# CIVA 2015

**EXTEN-D-E**
**CIVA**

# CIVA N·D·E 2015

*The simulation and analysis platform for NDE*

**CIVA 2015 proposes significant improvements** **from the CIVA 11.0 version**: In addition to simulation capabilities, CIVA is now a powerful analysis tool for acquisition data (M2M® systems, GEKKO®, Omniscan®, etc). Regarding the simulation tools, significant new capabilities are provided to the users (among which the ability to enter units in inches!). This version also includes a lot of issues corrections and optimizations.

**Don't miss this release to optimize your simulation works and discover the new analysis tools of CIVA!**

## CIVA is now a powerful tool for the analysis of your UT acquisition data:

As multiple acquisition systems are now compatible with CIVA UT (M2M systems, Omniscan®, etc.), many CIVA users want to use the CIVA to perform the **analysis of their acquisition files**. This is now possible with CIVA 2015.



*CIVA analysis window*

CIVA UT Analysis now includes the tools allowing to **easily and quickly extract indications from UT Data** (#id, depth, size, etc.) and to fill in an indication table that can be exported in ASCII file and/or prepare directly an examination report, including images, distances and comments by a simple click.

Memory performance has been enhanced as well as the GUI in order to efficiently perform such analysis works even on large industrial acquisition data files, including Phased Array technology.

Always wishing to propose cutting-edge features and not only basic ones, the indication selection cannot only be performed manually or based on classical "-N dB grouping" operations, although these operations are from now on really easy to do in CIVA, but a powerful algorithm called **"One Click Segmentation" is now available to automatically extract the relevant information in a given area** (even from the C-scan view).

Another one-click feature allows you to **see relevant data in the 3D view of the component**.

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This new version proposes both improvement of basic functionalities (cursors, measurement and selection tools, gates and limitations, A-scan time tracker, etc.) and powerful tools for advanced analysis (automatic & simplified segmentation as said above but also one click "-N dB grouping", advanced segmentation, **"Simulation – Acquisition" direct comparisons**, signal processing, hysteresis fixing, amplitude histogram, eraser, etc.) and data reconstruction (simple reconstruction, surface reconstruction, **Total Focusing Method**). Analysis environment is also adapted to **multi-sensor acquisitions** (links between different cursors, multi-burst layout).

Once the processing is performed on a given file, most steps of the procedure applied can be saved and are kept in memory in order to be able to do the job in several steps or to allow a real **traceability of the analysis process** and **a fast repeatable procedure**. These **templates** allow you to have several dedicated environment and processes **ready to use**.

These new analysis features are directly **included in CIVA UT** and can be used both for simulation and acquisition data. But it **can also be available in a standalone version** as a license of CIVA UT Analysis (i.e. without simulation tools but optionally with the CIVA beam computation module) to be used especially for data analysis, of course also on-site. Don't hesitate to contact us for pricing information for a license of CIVA UT analysis.

## *Improvement of CIVA simulation tools*

**CIVA 2015** also provides **new capabilities on the simulation side**:

**EMAT probes are now available in the GWT module**. As in CIVA UT (introduced in CIVA 11.0), this requires a coupling with the ET module in order to define the probe and compute Lorentz Forces generation. This GWT module is now integrated in the same window as the other modules of CIVA.
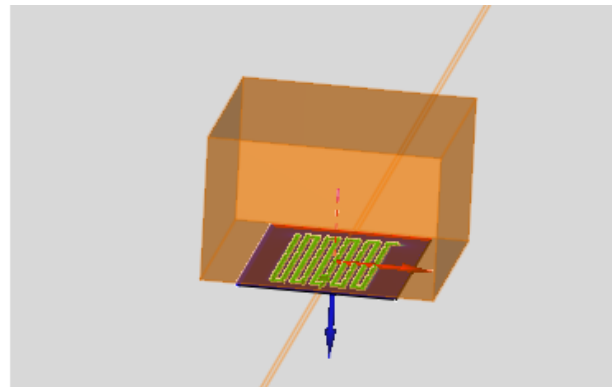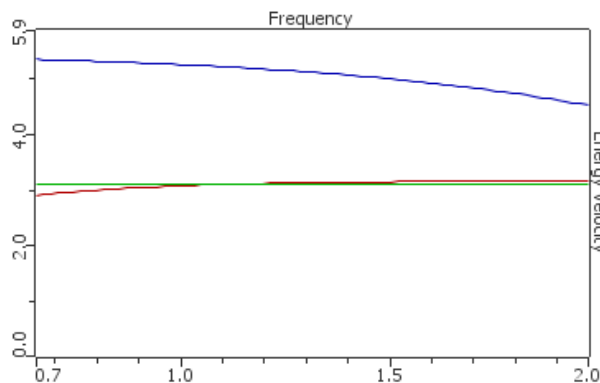


*EMAT probe in CIVA GWT*

In CIVA UT, some algorithms have been improved for beam/defect interaction: for instance, the SOV algorithm (more possibilities than Born model) is now available for cylindrical and spherical inclusions. Additionally, the specular algorithm has been added to the beam / flaws interaction algorithms in order to facilitate the simulation of **steel ball inspection in water**.

**Predict flaw detectability in RT thanks to simulation!** Detectability criteria had been implemented in CIVA 11.0 in the frame of a POD study. The detectability analysis is now available for any simulations in CIVA RT!

To precisely account for the scattering radiation in a CIVA RT simulation, it is sometimes (if not always) difficult to evaluate the required number of photons for the Monte-Carlo computation. CIVA 2015 includes a new tool that will automatically provide the **estimated number of photons for a good convergence of the Monte-Carlo** simulation. This should allow you to obtain good results in one shot and to avoid iterative trials or run computations with too many photons.
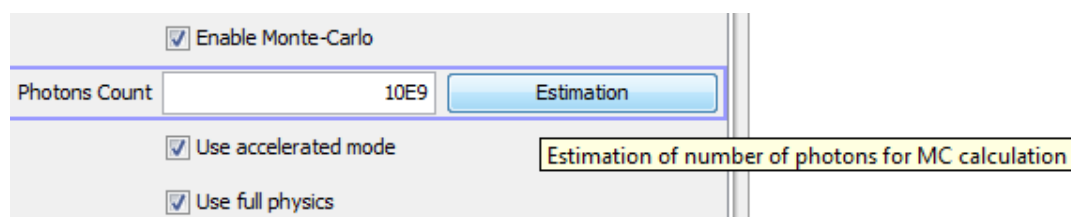


*Automatic Photons estimator*

Finally, in CIVA RT, a new model of detector is available as a "**generic detector**", aiming at allowing the user to enter any type of detector, including digital ones (such as flat panel), based on an experimental data file "Gray Level / Incident dose".

Regarding the Graphical User Interface (all modules of CIVA), one new feature, expected for years by our users in many countries, it is now possible to enter **dimensions in inches!**

By simply putting an "i" after the number, CIVA will interpret this input into inches. The conversion mm/inches will remain visible in a pop-up "sticker". In a similar idea, a user can also enter **fractional units: much more convenient** for geometries such as tubes or pipes where radius, diameter or wall thickness are usually provided in this unit!!
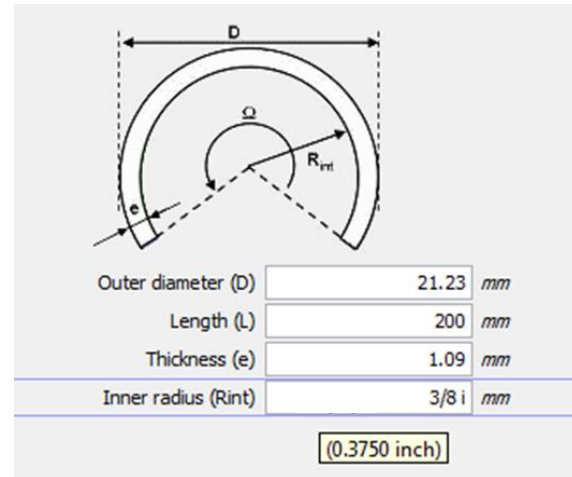


*Inches and fractional units now in CIVA GUI!*

As you know, CIVA never starts from a "blank page" when defining a new model but from a previous configuration kept in memory. This has advantages and drawbacks. To improve this, several **default configuration** options will be proposed in CIVA 2015 in order to start your models from a clean but relevant configuration.

Positioning options in CIVA UT have been changed in order to better fit with inspections practices. This new organization of the inspection panel is a first step to further changes in the future versions (regarding positioning and scanning).

When running a variation study, the output results were always given in "points". It is now possible to extract results directly in dB leading to an easier analysis.

# HARDWARE & SOFTWARE REQUIREMENTS

**Minimal configuration\*:**

- 64 bits OS == Windows 7 / Windows 8 / Windows 8.1
- Dual core
- Ram >= 8 Gb
- Hard Disk >= 250 Gb
- Graphic Resolution == 1280 x 1024 or 1920 x 1080
- DVD ROM
- USB port for Hardware dongle (Software key is proposed by default)

*\*Windows XP and 32 bits OS are no more supported (Windows XP is not supported any more by Microsoft).*

**Optimized configuration\*\*:**

- 64 bits OS   == Windows 7 / Windows 8 / Windows 8.1
- Hexa /Octo core
- Ram >= 24 Gb
- Hard Disk >= 500 Gb (with CIVA installed on SSD system disk 256 Gb)
- Graphic Resolution == 1920 x 1200
- DVD ROM
- USB port for Hardware dongle (Software key is proposed by default)
- GPU Graphic Processor (useful for CIVA CT only) with compute capability version >=2.x
  (http://en.wikipedia.org/wiki/CUDA#Supported_GPUs)
  For instance == GTX580 ou GTX TITAN

*\*\* An efficient use of CIVA CT requires this optimal configuration*

# UT SIMULATION

UT simulation tools include:

- **"Beam computation"** : Beam propagation simulation
- **"Inspection Simulation"**: Beam interaction with flaws or specimens

User can simulate a whole inspection process (**pulse echo, tandem or TOFD**) with a wide range of probes (**conventional, Phased-arrays or EMAT**), components, and flaws.

## Specimen

### Parametric geometries and CAD files:
The graphical interface allows the user to define the following geometries for the specimen:
- Canonical ones: Planar, cylindrical, conical, spherical
- Predefined component: **Nozzle**, **Weld templates** (13 different bevel profiles available), Turbine blade root and groove, Through Wall Penetration, Elbow, Plates with fasteners.
- **2D CAD files** containing a profile and generation of the 3D geometry either by translation or rotation of the profile: The profile can be homogeneous or heterogeneous. It can be defined either by CAD import (DXF or IGES format) or directly drawn by the user inside the 2D sketcher of CIVA.
- **3D CAD files** (IGES or STEP format): Homogeneous or **heterogeneous** solids, assembled structures with different solids
- Images (such as **macrographs**) can be imported in CIVA interface to help specimen definition and positioning

CIVA can also export specimen geometries in IGES format.
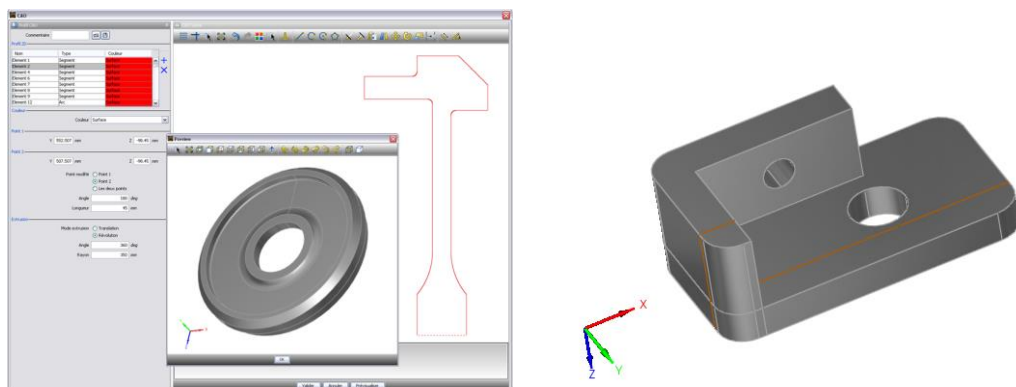


*CAD geometries*

### Materials

The component can be solid or fluid, homogeneous or made of several layers (e.g. cladding). Each layer may be isotropic or anisotropic, of arbitrary symmetry and orientation. Materials available are not only **metallic** ones but can also be **fiber composites** or granular composites (e.g. concrete). A new model called "polycrystalline" allows defining monophasic or biphasic grain structure based on the knowledge of the grain size. This model includes the calculation of **attenuation laws** and **structural noise**. Finally, simulations on « **coarse grains** » structures can be done by creation of volumes with the help of Voronoï diagrams. This model allows reproducing beam deviation phenomena, typical of coarse grain structures (e.g. cast stainless steel).

## Probes

A wide range of UT probes (standard and advanced designs) can be handled:
- Single element, dual element, **Phased-array** (see Phased Arrays section), **TOFD**, Tandem probes or **EMAT (involves a coupling with CIVA ET)**
- Contact or Immersion testing
- Rectangular, circular or elliptical radiating surfaces
- Focused probes via either shaped surfaces or probes with added acoustic lens
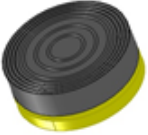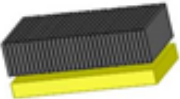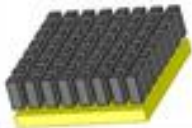- Planar or spherical/bifocal/Fermat focusing surfaces
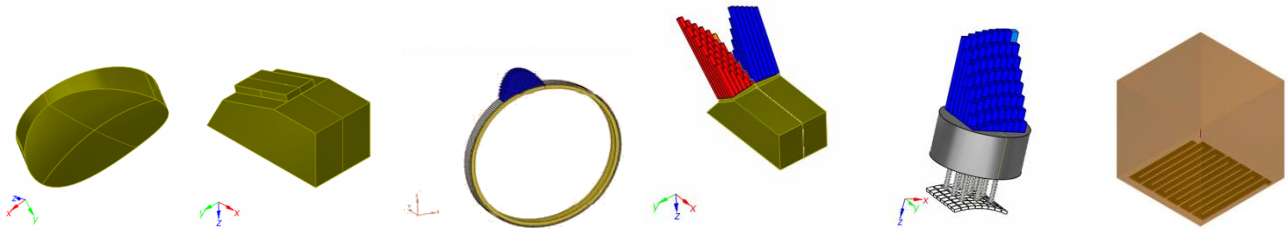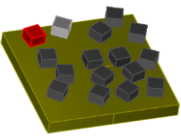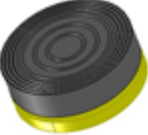
## Phased array Settings

A variety of phased-array transducers are available:
- Annular, **1D Linear**, **2D matrix**, 2D sectorial or elliptical patterns
- Encircled or Encircling curved arrays for tube inspection
- Flexible phased-array probe (in contact with parametric or CAD specimen, linear or matrix pattern).
- **Custom phased-array** (manual or random arrangement of elements)

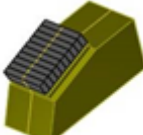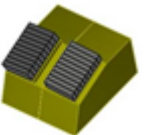| Annular | 1D Linear | 2D Matrix | 2D Sectorial | Sparse Array |
|---|---|---|---|---|
|  |  |  |  |  |
|  |  |  |  |  |
| Immersion | Contact | TR array | Flexible | Linear curved |

CIVA allows the user to compute delay laws and sequences of delay laws for standard and advanced phased-array techniques:
- Common or independent definition for transmitting and receiving elements
- **Electronic scanning**, simple or advanced (e.g. variable aperture at transmission or reception)
- **Full Matrix Capture**

**Delay laws** can be computed for specimens of arbitrary geometry (canonical or complex) and materials (homogeneous or heterogeneous materials, isotropic and anisotropic) from the simplest to the most advanced configuration:
- **Sectorial scanning**
- Focusing on one or several arbitrary points
- **Electronic scanning**
- Application of non-uniform amplitude laws (influence of non-homogeneous element responses, beam apodization)
- Application of dynamic delay laws (in case of complex geometries, delay laws can be computed independently for each probe position along the scanning axis).

CIVA also proposes Synthetic Focusing with the **Total Focusing Method** algorithm that can be applied to allow optimal reconstructions of flaw echoes and specimen boundaries. This processing allows, from an acquisition file or a phased-array simulation, the reconstruction of an image by combining signals in order to have the best focusing on a given zone.

## Flaws

An arbitrary number of flaws may be inserted into the component; these defects can be:
- Calibration defects: spherical pores, side-drilled holes, flat-bottom and hemispherical holes
- Planar defects, of arbitrary size and orientation, rectangular or semi elliptical
- Multifaceted defects,2D CAD contour defects, **Branched defects**
- Solid inclusions (cylindrical, spherical or elliptical shapes)

## Results

### Beam Calculation

A first module simulates the ultrasonic beam in the specimen and if asked in the coupling material.

The beam can be displayed in the specimen as an amplitude color coded image or as an iso-amplitude surface. Local orientation of the beam and wave fronts can be displayed (and saved as animated files, AVI format). For phased-array probes operating in multiple shots mode (e.g. sectorial scan), both single beam and cumulated beam can be displayed.
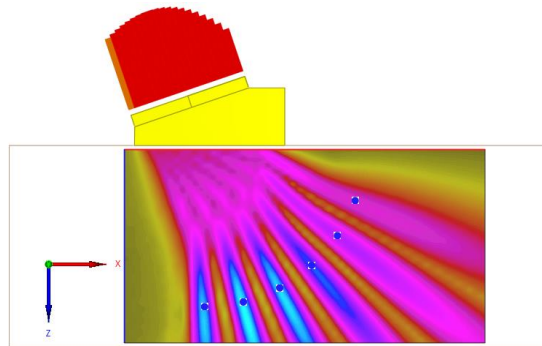


*Beam with multiple shots PA probe*

### Inspection Simulation

This module simulates the **beam-defect interaction** and predicts the amplitude and the time of flight of various echoes: **direct echo, corner effect, tip diffraction echo**, etc. The number of skips has no limit. It can also calculates echoes scattered back by the geometry (backwall, entry surface and interior specular interfaces echoes), takes into account mode conversions and in some cases creeping waves.

For TOFD configuration, direct tip echoes generated by the edge of the defects are simulated as well as **lateral waves**. The list of modes allows the user to choose which modes to calculate.

**POD calculations** (Probability Of Detection) are available, based on the accounting of uncertain input parameters.
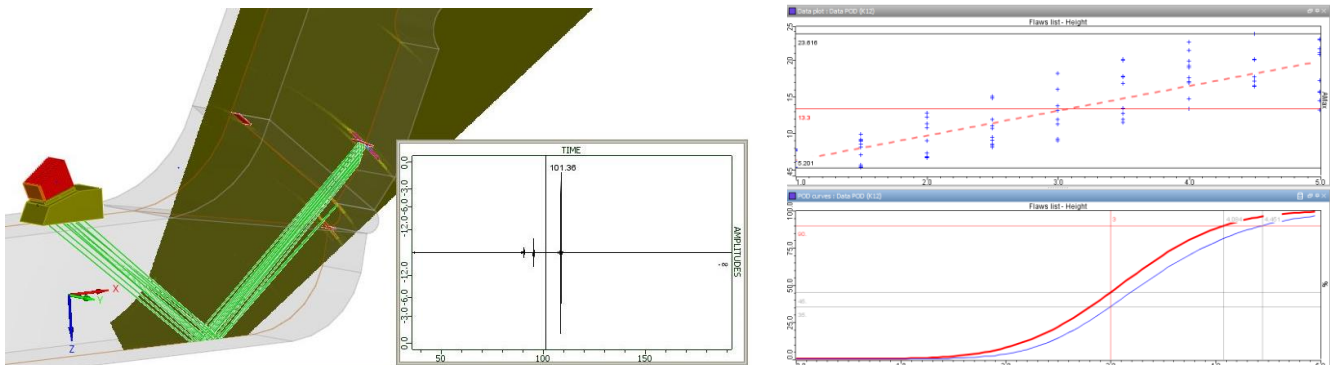


*Inspection simulation results: S-Scan, A-Scan, POD curve, etc.*

### Analysis tools

Results are provided as classical UT data (A-Scan, echodynamic curves) or more **advanced images** (B-Scan, C-Scan, S-Scan, E-Scan, etc.) that can be reconstructed and **superimposed on the work piece**, allowing an optimal understanding of physical phenomena.

**Acquisition Gates** can be defined a priori or a posteriori. A **mode identification tool** allows identifying the different modes that contributes to an echo. A **ray tracer** completes these tools (it takes into account mode conversion, reflections, displays time of flight, etc.). This tool is connected to the list of modes, and helps in understanding different interactions. All results can be exported in ASCII files (A-Scan, C-Scan, POD curve, etc.).
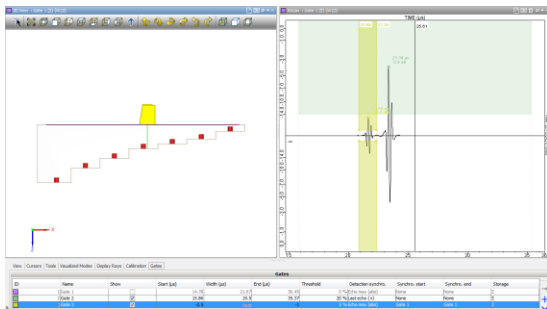


*Acquisition gate definition*
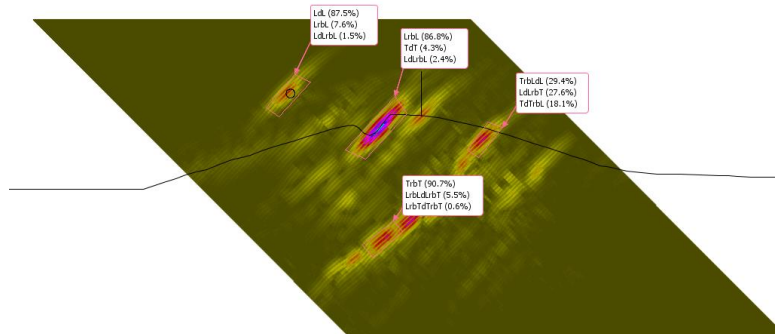


*Mode identification tool*

In addition to simulation results, CIVA can import and post-process real acquisition **data files**. Therefore, **the simulation software benefits from all features available in the UT analysis** tool (see next part): Analyse your simulations as you do for real acquisitions thanks to CIVA UT Analysis!

**Discover more about the UT module at**

**http://www.extende.com/ultrasonic-testing-with-civa**

# CIVA UT ANALYSIS

The CIVA UT Analysis module's main objectives are to display acquisition DATA in an easy and understandable way, to extract advanced information in an efficient way, to put this data into a dynamic report and to avoid repeatable and time consuming manipulations.

## Basic… But necessary tools

Data is displayed as **classical UT data** (A-Scan, echodynamic curves) or more **advanced images** (B-Scan, C-Scan, S-Scan, E-Scan, etc.). Images in the **specimen frame** can also be displayed (Front, top, side sections or full views) and the data can be exported in the 3D view with the specimen as 2D images or directly as 3D with the **"one click 3D view".** Note that images can be built from amplitude, depth or time of flight.
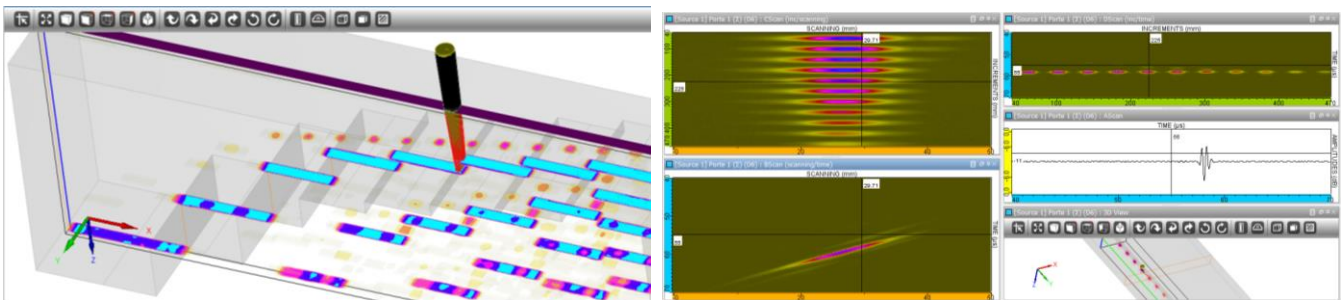


**Zooming** is easy and fast. From the active zoom, an extraction can be performed that creates a **new Dataset.**

The **Color map** can be adjusted. A **double cursor** is available along with all classical tools for images (**mirrors**, rotation, copy and paste, distance measurements…).

Acquisition **gates** can be added, adjusted in time (reduced) and even **synchronized** (on specific echoes) to recreate a new data set.

A new and very useful feature is the **amplitude histogram,** which is created in one click for a selected ROI. It represents the number of points having the same amplitude for all amplitudes in the ROI.

If you have some mechanical play in your system, you can easily improve your acquisition data with the **Hysteresis correction**.

A **Ray tracer** is available with a direct link to the time cursor so that you can easily identify complex echoes. The Ray Tracer is the one from CIVA UT, with all its possibilities included.

## Advanced tools: the one-click advantage

The objective to easily and quickly extract interesting information has been reached, through first, the selection of a region of interest (ROI), then through **one-click tools such as "-xdB contour" or Segmentation**. Note that Segmentation makes groups automatically represented in the 3D display.
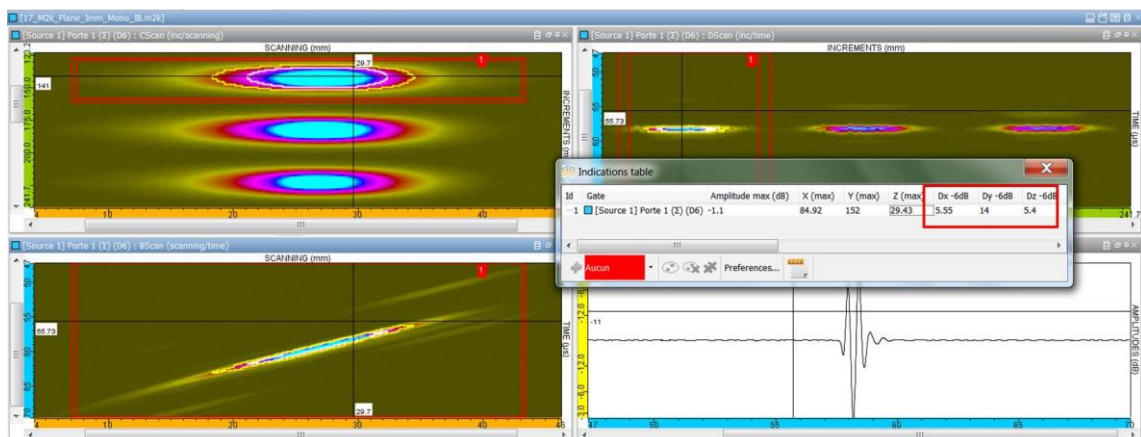
Relevant information (amplitude, position, size…) is included in an **indication table** in one click: **images**, distances, type of indication or other comments can be added. Multiple indications can be grouped as one indication. Columns of this indication table can be selected, sorted among a long list of available data.

This indication table can be **exported in CSV format** or an **HTML report** can be generated in one click.



Indications table

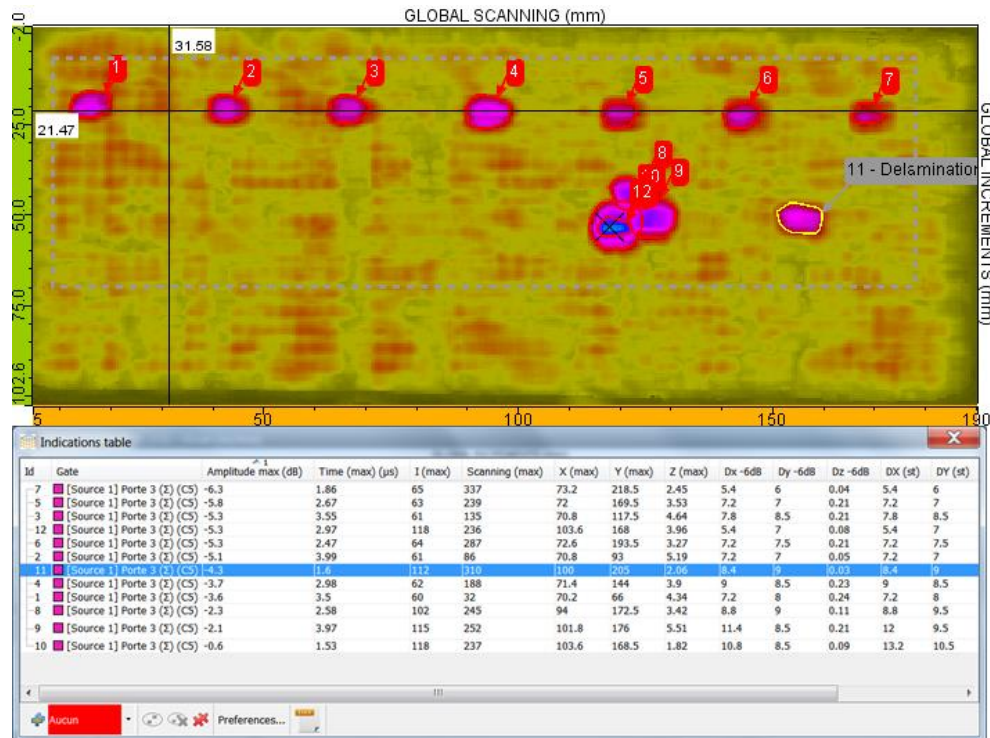| Id | Gate | Amplitude max (dB) | Time (max) (µs) | I (max) | Scanning (max) | X (max) | Y (max) | Z (max) | Dx -6dB | Dy -6dB | Dz -6dB | DX (st) | DY (st) |
|----|------|--------------------|------------------|---------|----------------|---------|---------|---------|---------|---------|---------|---------|---------|
| 7 | [Source 1] Porte 3 (Σ) (CS) | -6.3 | 1.86 | 65 | 337 | 73.2 | 218.5 | 2.45 | 5.4 | 6 | 0.04 | 5.4 | 6 |
| 5 | [Source 1] Porte 3 (Σ) (CS) | -5.8 | 2.67 | 63 | 239 | 72 | 169.5 | 3.53 | 7.2 | 7 | 0.21 | 7.2 | 7 |
| 3 | [Source 1] Porte 3 (Σ) (CS) | -5.3 | 3.55 | 61 | 135 | 70.8 | 117.5 | 4.64 | 7.8 | 8.5 | 0.21 | 7.8 | 8.5 |
| 12 | [Source 1] Porte 3 (Σ) (CS) | -5.3 | 2.97 | 118 | 236 | 103.6 | 168 | 3.96 | 5.4 | 7 | 0.08 | 5.4 | 7 |
| 6 | [Source 1] Porte 3 (Σ) (CS) | -5.3 | 2.47 | 64 | 287 | 72.6 | 193.5 | 3.27 | 7.2 | 7.5 | 0.21 | 7.2 | 7.5 |
| 2 | [Source 1] Porte 3 (Σ) (CS) | -5.1 | 3.99 | 61 | 86 | 70.8 | 93 | 5.19 | 7.2 | 7 | 0.05 | 7.2 | 7 |
| 11 | [Source 1] Porte 3 (Σ) (CS) | -4.3 | 1.6 | 112 | 310 | 100 | 205 | 2.06 | 8.4 | 9 | 0.03 | 8.4 | 9 |
| 4 | [Source 1] Porte 3 (Σ) (CS) | -3.7 | 2.98 | 62 | 188 | 71.4 | 144 | 3.9 | 8.5 | 9 | 0.23 | 9 | 8.5 |
| 1 | [Source 1] Porte 3 (Σ) (CS) | -3.6 | 3.5 | 60 | 32 | 70.2 | 66 | 4.34 | 7.2 | 8 | 0.24 | 7.2 | 8 |
| 8 | [Source 1] Porte 3 (Σ) (CS) | -2.3 | 2.58 | 102 | 245 | 94 | 172.5 | 3.42 | 8.8 | 9 | 0.11 | 8.8 | 9.5 |
| 9 | [Source 1] Porte 3 (Σ) (CS) | -2.1 | 3.97 | 115 | 252 | 101.8 | 176 | 5.51 | 11.4 | 8.5 | 0.21 | 12 | 9.5 |
| 10 | [Source 1] Porte 3 (Σ) (CS) | -0.6 | 1.53 | 118 | 237 | 103.6 | 168.5 | 1.82 | 10.8 | 8.5 | 0.09 | 13.2 | 10.5 |

In parallel, to help with the diagnosis, multiple functionalities are available: a wide range of **signal processing methods**, some are classical (filters, etc.), others are more sophisticated (wavelets transforms, deconvolution methods, Split Spectrum).

The stand-alone version of CIVA UT Analysis module also proposes **simulation in a ROI**, based on the diagnosis you want to try (planar defect).
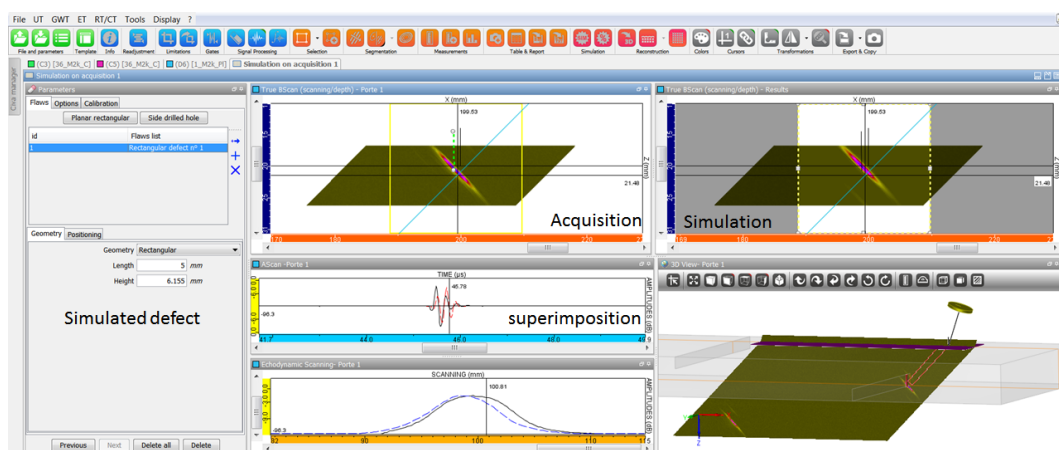


If you use the latest techniques like **TFM** (total focusing method), you can make appropriate **reconstructions** and even redraw the surface of your specimen in one click.

A **data eraser** facilitates multiple points selection with the exclusion of a global region. This can be very useful and efficient and remains safe as a new data set is created and the original one remains unchanged.

**Calibration** can be adjusted as a post processing. A **DAC correction** can also be made on the Data.

## Make your work environment more efficient

You can **customize** your use of CIVA UT Analysis to drastically reduce repeatable actions, to have a convenient environment, and to integrate part of your different analysis procedures.

If you perform multi-salvo inspections (or multi probes in the same data file), CIVA now offers the possibility to work on these salvoes with links between cursors and to modify the settings of each transducer position and the reference position (origin) of the specimen.
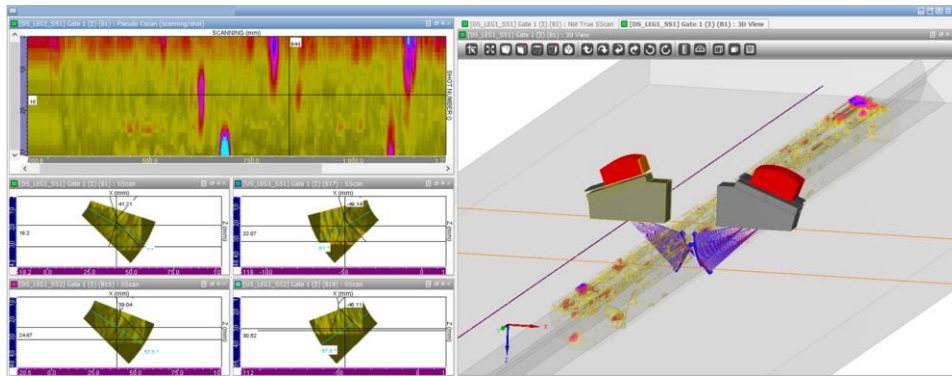


**Layouts** are still available that let you place the images where you want, with the size and the contents you define. Give a name to each layout and recall it when you need.

In the preferences, "user **profiles"** with different names can be created. In these profiles, **three default thresholds** can be defined for "contour at –xdB", the **contents of the report** (contents and order of each column) can be adjusted, and the **type of defects** (names for indications such as cracks, volumetric, corner echo, geometrical echoes…) can also be created. Each of these profiles can be loaded at any moment.

Last, but not least, part of your work can be defined as a **template**. This means that you can give a name to some of the actions you currently do (for example add a gate, synchronize it, open a new tab, make a limitation in it…) and this operation will be **completely automatic** when you recall it for a similar file: avoid errors, save time and put your efforts on the real work of analysis!

## Delay laws calculator

CIVA UT Analysis lets the user compute the delay laws and sequences of delay laws for standard and advanced phased-array techniques. CIVA UT analysis includes **all possibilities of CIVA UT regarding Delay laws computation** (see previous description of the CIVA UT simulation module for more details).

## Beam Calculation and Delay laws export (optional)

It is possible to include in your CIVA UT analysis package, the beam computation module of CIVA (simulation), described in the previous part. With this option, the delay laws calculator also let the possibility to export this information in *.raw and *.pte ASCII files. It includes both delay laws and index point's data.

**Discover more about the UT ANALYSIS module at:**

**http://www.extende.com/ultrasonic-testing-analysis-with-civa**

## CIVA 2015 - UT ANALYSIS MODULE
## Features list

| Basic features | |
|---|---|
| | Classical images (A-Scan, B-Scan, C-Scan, D-Scan…) |
| | PA Images (S-Scan, E-Scan…) |
| | 2D scan images superimposed onto the 3D part |
| | Specimen reconstruction (from simple to 3D CAD specimen) |
| | Amplitude measurement & Calibration |
| | Distance measurement (3D) |
| | TOFD Calibration |
| | Report in HTML or export in CSV |
| | Zooming & Image tools (mirrors, rotation, flip, export…) |
| | Delay laws calculator (includes management of electronic scanning) |
| | Display in amplitude, depth or time of flight |
| **Advanced features** | |
| | Reconstruction with material and geometrical influence |
| | Hysteresis correction |
| | 3D evolved ray tracer with time of flight connection |
| | Layout definition and back-up |
| | DATA Eraser |
| | Complete traceability of actions modifying Data |
| | Acquisition gates addition, modification and synchronization |
| | One-click amplitude histogram with mean values, max… |
| | "-x dB" automatic contour (Also added in report) |
| | Signal processing (filters to wavelets or split spectrum…) |
| | DAC corrections |
| **Cutting edge features** | |
| | One-click segmentation with 3D representation |
| | One-click 3D full DATA export |
| | UT Simulation on defects in a ROI |
| | Templates for most processing with naming and back-up |
| | Customization of report column, environment, thresholds… |
| | TFM reconstructions |
| | Surface reconstruction |
| **Optional features** | |
| | UT Beam simulation |
| | Delay Laws export |

| | |
|---|---|
| Accepted format | M2M systems, Gekko, Olympus Data (need Library) |
| Language | Available in English and French |

# *CIVA ATHENA 2D*

## The ease of use if CIVA, the power of Finite Elements… but fast!

CIVA ATHENA 2D is an "add-on" module available with CIVA UT. This tool consists in a hybrid module, using both conventional semi-analytical methods of CIVA and the FEM code ATHENA (from EDF). The connection with Finite Elements allows taking into account **more complex phenomena** that can occur in a UT inspection.

## The FE box

In CIVA ATHENA 2D, a finite element rectangular box is defined. Out of this box, the UT beam propagation is modeled with the conventional CIVA semi-analytical pencil method. In the box, calculation is made by FEM using the incident beam calculated on the box boundaries as an input. Typically, FEM will be used to simulate UT beam/defect interactions (and beam/geometry interactions) whereas the fast semi-analytic model is used to simulate the round trip propagation of ultrasounds from the transducer.
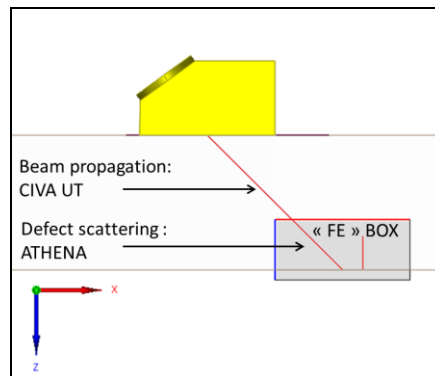


## Simulation Examples: Take into account all phenomena

The interest of CIVA ATHENA 2D is to account for all physical phenomena in the beam/defect interaction:

- Accounts for creeping waves and Rayleigh waves generated on flaws
- Simulates multiple scattering by flaws
- Precisely calculates the response from small flaws with respect to the wavelength
- Computes interface echoes
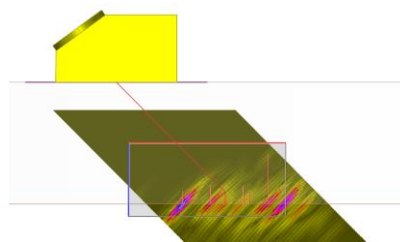


*Network of flaws (multiple scattering)*
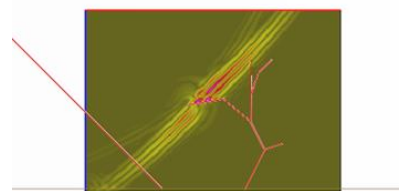


*Complex flaws and creeping waves generated*

These possibilities allow precisely simulation of the response from clusters of flaws or from complex flaw profiles accounting for multiple reflections and the generated surface waves.

## Specimen

Even if 3D effects are ignored, no restriction is made on the available components in the user interface compared to CIVA UT. As this is a 2D module, to give quantitative results, the user shall consider component geometries that can be locally considered as 2D, or at least that makes sense in 2D.

## Probes

As this is a 2D code, only a 2D section of the transducer is modeled. But no restriction is made in the transducers available in the user interface. User will pay attention to the defined transducer (in terms of focusing or crystal shape) so that the 2D simulation makes sense.

The scanning of the probe will be in the incident plane only as the 2D box is fixed in this plane.

Tandem configurations are allowed but only make sense if the incident and reflected beam at the box boundary is a direct beam for both the transmitter and emitter.

TOFD configurations are also available but only with a scanning in the incidence plane.

## Phased-Array Settings

The phased array settings of CIVA UT are available in CIVA ATHENA 2D but the calculation is done only for one shot and one sequence at a time.

## Flaws

The flaws that can be defined by their 2D cross-section are available: Planar, multifaceted, branched, Side Drilled Holes.

## Results: Visualize beam/defect scattering

In addition to the classical curves and images already available in CIVA UT (A-scans, B-scans, 3D view, reconstructed view, etc.), CIVA ATHENA 2D allows visualizing defect scattering phenomena by displaying snapshots of the beam in the FEM zone (maximum amplitude, or propagation versus time and video).
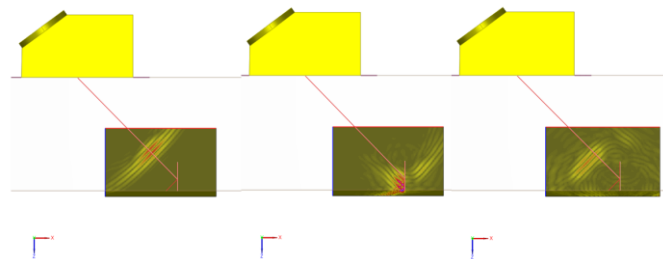


*Snapshots of the beam/flaw interaction vs time*

## Simulation remains easy and fast

In addition to its advanced capabilities, the coupling between CIVA & ATHENA has other advantages: the computation is **faster than** a complete **Finite Element computation**, while **all phenomena are accounted for** regarding the beam/defect interactions. The configuration is defined in the **user-friendly** CIVA interface, with very few specific parameters for the FEM calculation. Therefore, CIVA ATHENA 2D is **easy to use**.

## CIVA ATHENA2D ….is a 2D module

CIVA ATHENA 2D uses a 2D beam computation and a 2D FEM calculation from ATHENA. Therefore, 3D effects are intrinsically ignored, while it gives **very precise results as soon as the 2D hypothesis can be credited**, which mainly means:

- Considering only flaws that can be defined by their 2D cross-section: planar notches, multifaceted or branched flaws and Side Drilled Holes
- Comparing flaws response independently from their extension in the orthogonal plane: same extension and at the same depth, or extension larger than the beam width
- Component geometries that can be locally considered as 2D

Besides 2D configurations, using CIVA ATHENA 2D remains interesting for qualitative analysis.

**Discover more about the CIVA ATHENA2D module at**

**http://www.extende.com/ultrasonic-finite-elements-with-civa-athena2d**

# *GWT SIMULATION*

Simulation capabilities for guided waves include the propagation of ultrasonic beams in planar and tubular waveguides and their interaction with a flaw.
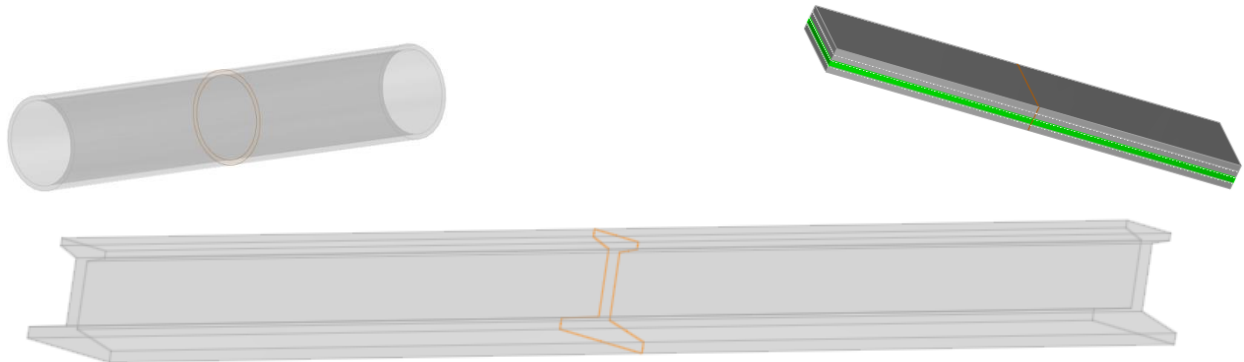
## PROBES

A wide range of UT probes, including standard and advanced designs can be handled:

- Contact (with or without wedge)
- Single element, phased-array probes (see Phased Arrays section) or EMAT probes (involves a coupling with CIVA ET)
- Encircling or encircled probes for pipe inspection
- Different types of waves (shear or longitudinal vibration)
- Different configurations (Pulse-Echo, Pitch-Catch transmission or Pitch-Catch reflection)
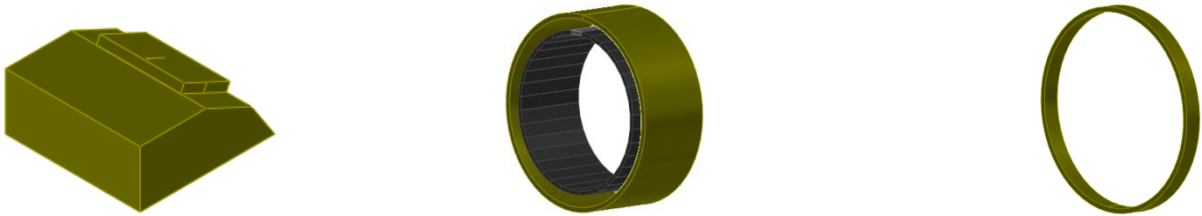


## SPECIMEN

Planar structures and pipe-like structures (with possibly some discontinuities) are considered for guiding waves by CIVA. The specimen may be homogeneous or heterogeneous, taking into account a coating for example. Each medium should be isotropic and linear attenuation laws may be considered for L-waves and T-waves. This is also possible to account for pipes filled with fluid or to compute modes and beams on parts having 2D CAD cross section, such as rails:



## PHASED-ARRAYS settings

With CIVA you can define delay laws for different kinds of probes: linear arrays on plates, encircling or matrix arrays on pipes:



| Linear | Matrix | Encircling | 2 encircling array probes |
|---|---|---|---|
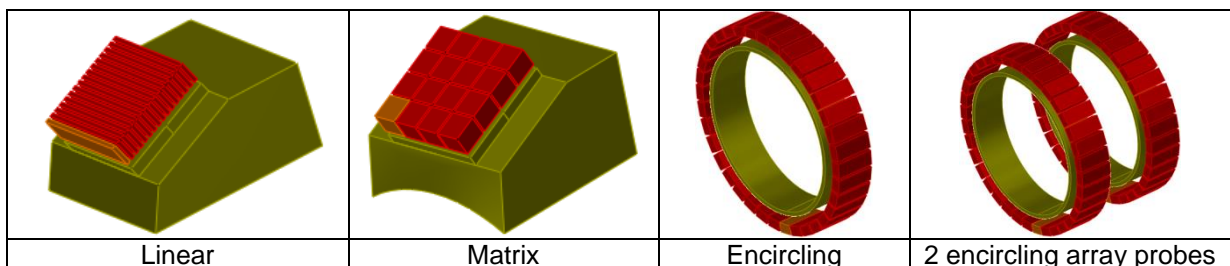
- Independent definition of emitting or receiving elements
- Variable aperture at emission or reception, for size or position

In the case of pipes, CIVA 11 GWT allows the user to compute delay laws in order to focus on a given point of the pipe, as long as the excitation frequency is lower than the cut-off frequency of mode L(0,3).
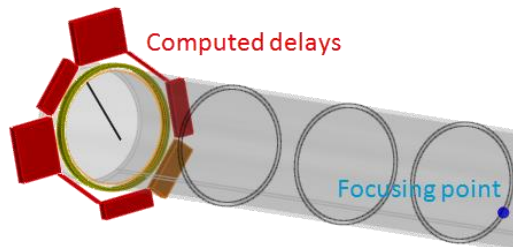


## FLAWS

Simulation takes into account a flaw perpendicular to the waveguide, rectangular on a plate, sectorial on a pipe, and determines its interaction with the incident guided beam.
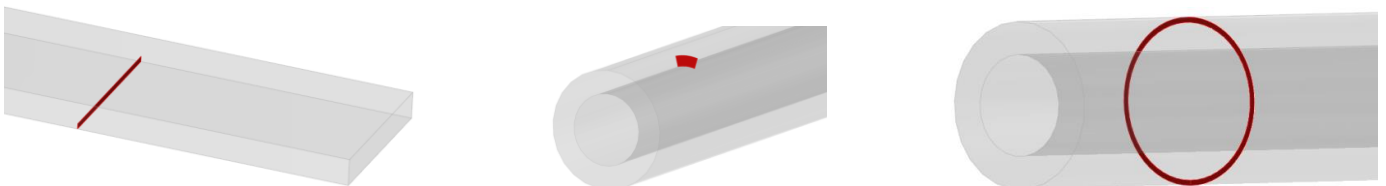


Since CIVA 11 GWT, 2D geometrical discontinuities, such as a weld, a groove, a transition (varying diameter) or a junction between straight parts, can be handled for echoes prediction. One or several axisymmetrical flaws can then be accounted for in this discontinuity.
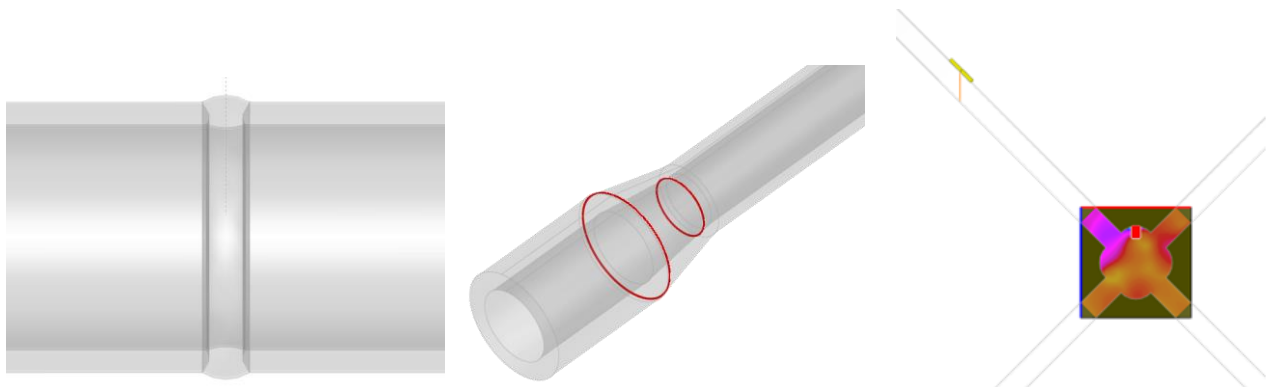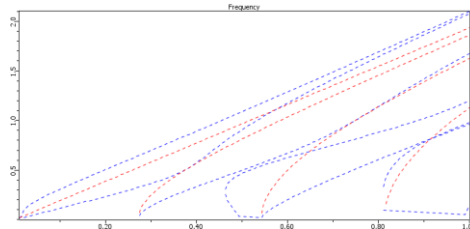
## RESULTS

### Mode computation

A first module computes the dispersion curves associated with the specimen in a given frequencies range.

Modal displacements and constraints are computed for each mode at each frequency of the frequencies range.



### Field computation

A second module allows simulating the ultrasonic beam radiated in different cross-sections of the specimen. The modal repartition of the emitted energy is displayed versus the frequency in the bandwidth of the probe.

The displacement and constraints are determined in a time range, which allows visualization of the transit of the different waves at each cross-section or the verification of the focusing allowed by a delay law.
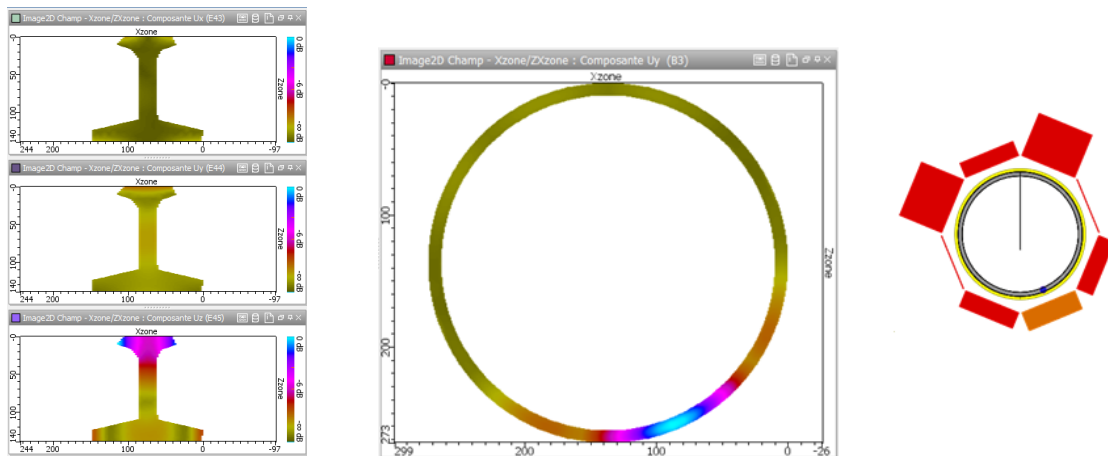


### Defect response

This module simulates the beam/flaw interaction (or beam/geometrical discontinuity) and predicts the amplitude, waveform and time of flight of the different types of echoes: incident, reflected and mode converted.

On a weld, a preview helps the user to estimate the reflection coefficient of the first torsional mode on the weld, depending on the excitation frequency.
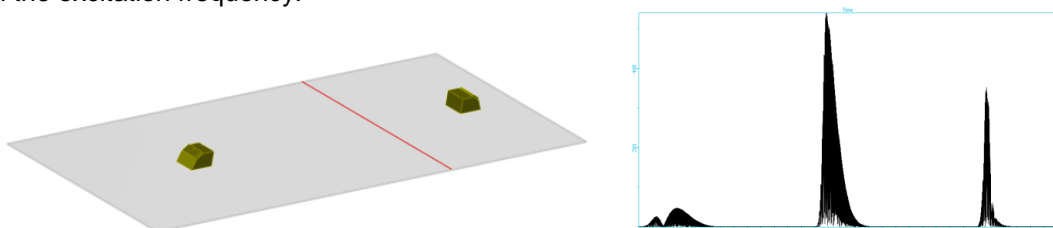


**Discover more about the CIVA GWT module at**

**http://www.extende.com/guided-wave-testing-with-civa**

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# ET SIMULATION

The CIVA ET simulation tool proposes three modules:
- **"Field Computation"**, that allows predicting:
  - Eddy current density and electric field induced by an ET probe in a conductive component
  - Magnetic Induction generated by an ET probe in the component, the air, or the sensor itself
- **"Inspection Simulation 3D"**: in order to simulate the inspection of work pieces that include various type of flaws
- **"Inspection Simulation 2D cyl."**: in order to simulate the inspection of an axisymmetric component including axisymmetric flaws (e.g. groove)

## Specimen

**Parametric geometries and 2D CAD profile**:
The graphical interface allows the user to define the following geometries for the specimen:
- Field Computation module: Planar (possibly multilayers) and cylindrical
- Inspection Simulation 3D: Planar (possibly multilayers), cylindrical and multilayers **fastened plate**,
- Inspection Simulation 2D Cyl. : Cylindrical, expanded tube with tube sheet or 2D CAD profile
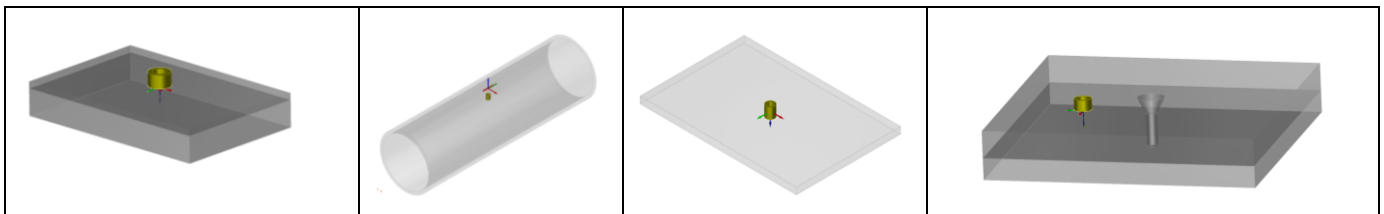


*Some of the available component geometries: Cylinder, Plate, Multilayers plate, Fastened plate*

**Materials**

User defines the conductivity and the relative permeability of the component (constant values). One can also select directly the material in a predefined database including about twenty classical metals.

## Flaws

Several flaws of different types can be defined in the test piece:
- Flat Bottomed Holes in tubes and planar components,
- Longitudinal or transverse notches in tubes,
- Internal or external grooves in tubes,
- Parallelepiped flaws in planar or fastened pieces,
- Semi-elliptical or quarter-elliptical notches in plates or fastened pieces.

Flaws can be voids, metallic inclusions or partially filled with materials ("bridge contacts" defect type). Several flaws can be combined (i.e. crossed), surface breaking (i.e. positioned on the inner side or on the opposite side), or sub-surface (embedded inside the work piece with a defined ligament).

## Probes

The ET module proposes a library of numerous types of sensors:

- For planar work pieces inspection: **Numerous shapes of coils available** such as cylindrical coil, rectangular coil, D-coil, Racetrack, meander, Spiral circular or rectangular ones (see pictures below)
- For tubular work pieces inspection: **Rotating probes** with different shapes (as defined above) and also **bobbin coil**, encircling coil or sectorial coil
- GMR like magnetic sensors,
- **ECA sensors** (Eddy Current Arrays)
- **EMAT probe (Lorentz Forces computation, in order to be exported towards the UT and GWT modules)**

A **ferrite core** can be added to a coil. The ferrite core can be a cylindrical one, or can be a C or E-shaped pot. A shield ring can also be represented.

CIVA allows the user to simulate multi-sensors and multi-frequencies channels. Several acquisition channels may be defined in a single simulation: Absolute, differential, reflection (separated transmit/receive) at different frequencies.

Different phenomena such as variations of lift-off tilt angles and off-centering in tubes can be accounted for.
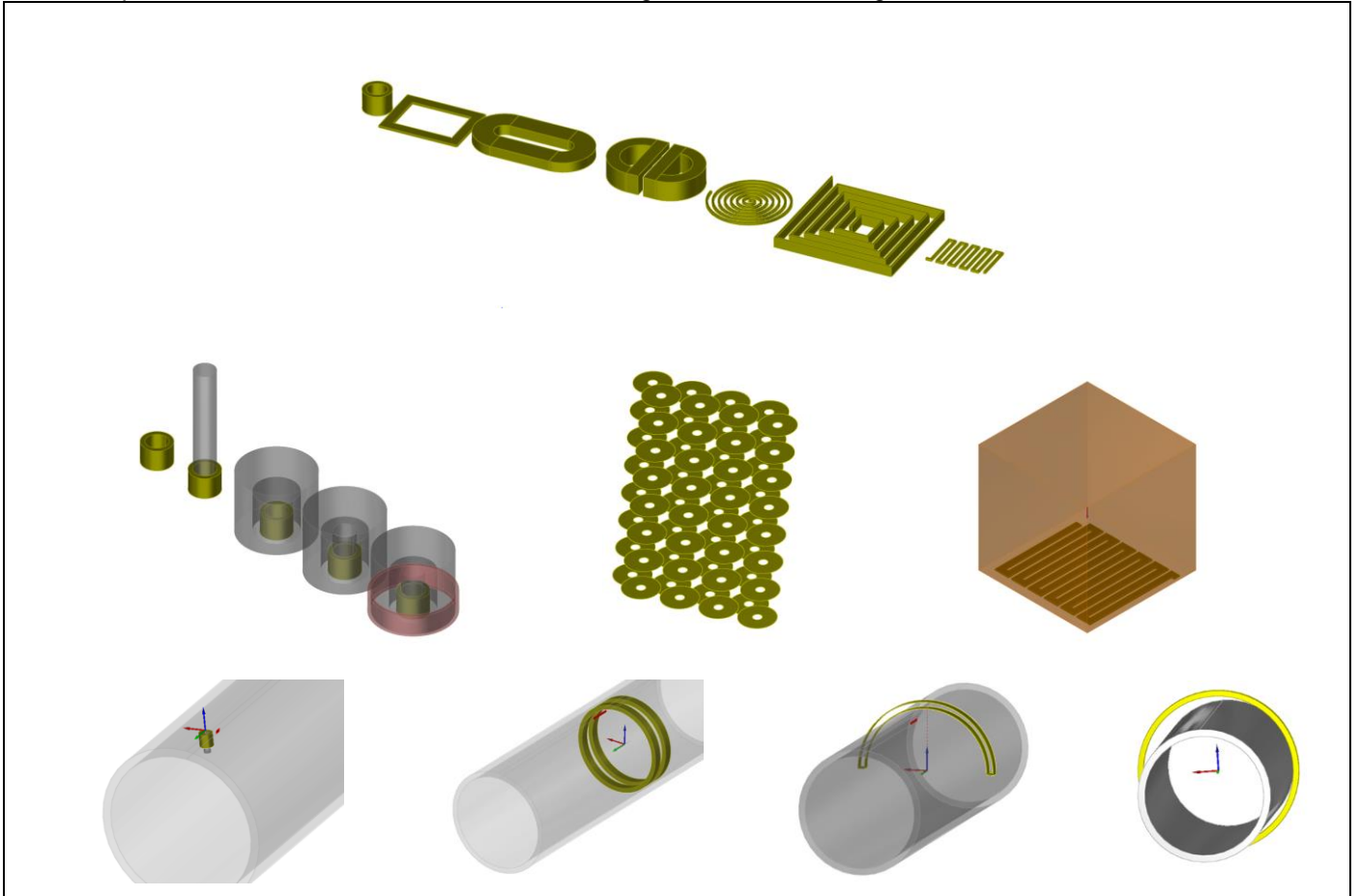


*Various ET probe configurations in CIVA: Numerous shapes of coil available, rotating probe or bobbin coil in tubes, bobbin coils, encircling coil, sectorial coil, EMAT probe, Eddy Current Arrays*

## RESULTS

### Field and impedance computations in free-flaw components

The field computation module proposes a fast analytical calculation tool for flaw-free planar work pieces. Several quantities can be displayed: Eddy-current density, electric field or magnetic induction. The **normalized impedance diagram** of a probe can be plotted for various working frequencies facilitating finding the best operating frequency. The **lift-off signal** (i.e. impedance change due to lift-off variation) in the impedance plane can be also calculated and displayed.
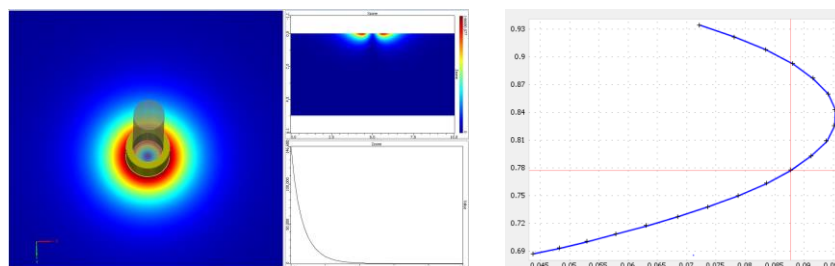


*Some results available in the Field Computation module: Eddy Current induced in the specimen, Frequency response of the sensor (normalized impedance diagram)*

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## Inspection simulation 3D

In Inspection Simulation 3D, the user can simulate the inspection of tubes, planar and fastened components having one or several defects (possibly combined), selected among the available list of defects presented above. The sensors scanning can follow linear trajectories, transverse or helicoidal ones.

In planar or fastened specimens, several materials at several conductivities can be defined in different layers.

In tubular work piece, only a single material will be assigned. This one can be ferromagnetic as CIVA can model the **remote field technique** for ferromagnetic tubes inspections (so-called RFT).

A **multi-channel mode** gives the possibility to compute in one shot of simulations, several acquisition channels (absolute, differential…) at one or different frequencies. **POD calculations** (Probability Of Detection) are available, based on the accounting of uncertain input parameters.
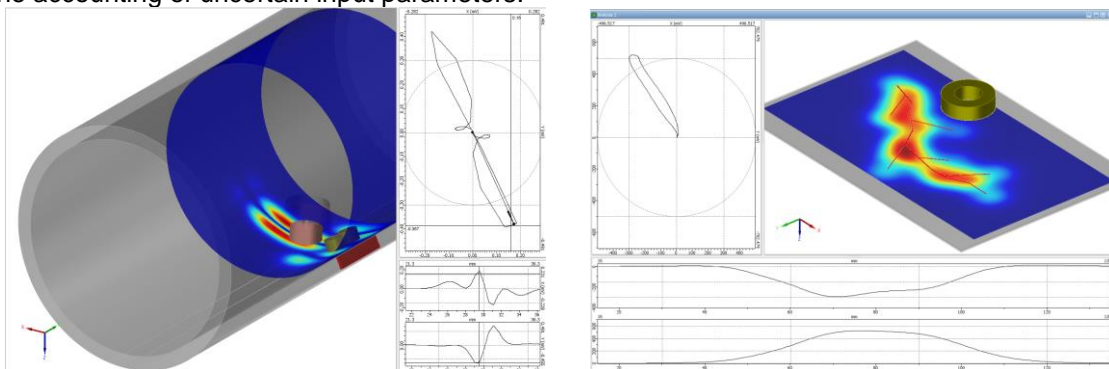


*Eddy Current Inspection Simulation: Tube inspection with a rotating probe, Inspection with a complex crack*

A dedicated post-processing tool displays the impedance variation signal due to the flaw(s). Results are displayed with a Cscan colored chart or conventional curves in the impedance plane. The environment provides access to classical results for an ET analysis (Amplitude, Phase, X and Y channel, Impedance plane) as well as other tools to process data: Calibration, Frequency mixing, Interpolation, Balancing, and Filtering.

## Inspection simulation 2D cyl.

In Inspection Simulation 2D Cyl, the user can simulate the inspection of perfectly cylindrical tubes, that can be coated, and also non-canonical geometries such as **tube expansion zone** (existing in tubes exchanger) or irregular tube profiles defined by a 2D CAD file (using an import of an original CAD file or drawn inside CIVA).

The sensor and the flaw will be also axisymmetric. A linear scan will be simulated and results will be provided in the impedance plane or for the X and Y channel versus position.
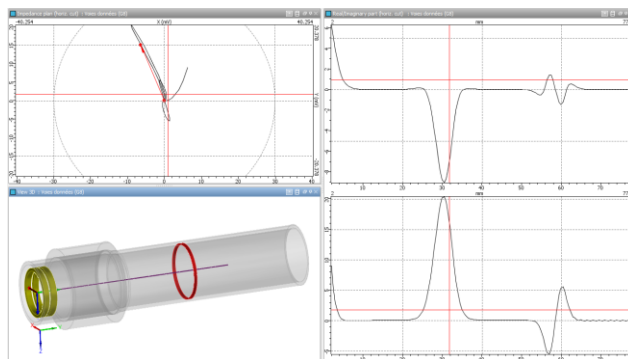


*Inspection of a tube transition zone in a tube exchanger*

**Discover more about the CIVA ET module at**

**http://www.extende.com/eddy-current-testing-with-civa**

# *RT* SIMULATION

The RT simulation module can compute direct and scattered radiation produced by an X-ray or Gamma-Ray source. The user can easily and rapidly define its control configuration: Test piece selection, source definition, detector, possibility to insert several flaws, positioning of source and detector, and finally computation options. **Digital Radiography** can also be simulated.
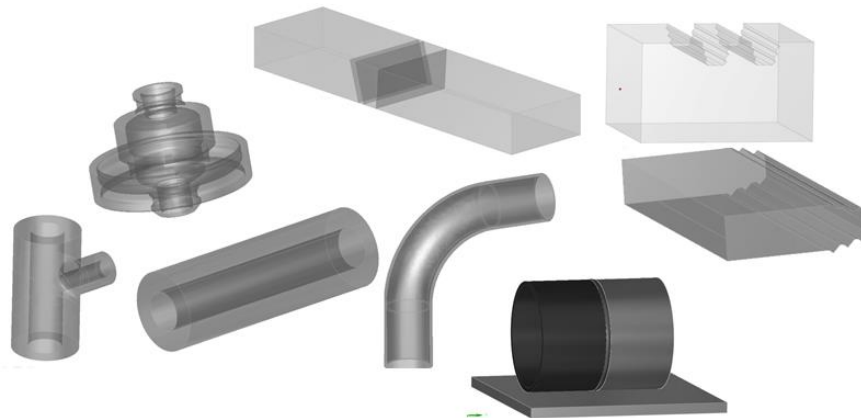
## *Specimen*

### *Parametric geometries and CAD files:*
The graphical interface allows the user to define the following geometries for the specimen:
- Canonical ones: Planar, cylindrical, conical
- Predefined component: **Nozzle**, **Weld templates** (13 different bevel profiles available), Turbine blade root and groove, Through Wall Penetration, Elbow.
- **2D CAD files** containing a profile and generation of the 3D geometry either by translation or rotation of the profile: The profile can be homogeneous or heterogeneous. It can be defined either by CAD import (DXF or IGES format) or directly drawn by the user inside the 2D sketcher of CIVA.
- **3D CAD files** (STL, IGES or STEP format): Homogeneous or **heterogeneous** solids, assembled structures with different solids. It is also possible to import several objects and simulate some backscattering phenomena.

CIVA can also export specimen geometries in IGES format.



*Examples of component geometries*

### *Materials*

The material is defined from an available database including **more than 110** elements and alloys, with the associated **cross-section data**. The specimen can be homogeneous (1 single material) or heterogeneous.

## Source
- Radiation :
  - o **X-ray Source**: One defines the intensity of the source in Ampere and the spectral contents of the photons radiated by the source. This spectrum can be defined:
    - By selection in a catalogue proposing predefined ones (Birsh-Marshall)
    - By manual settings
    - By using a spectrum calculator embedded in CIVA based on the physical parameters of the source entered by the user: anode ( angle & material) & voltage
  - o **Gamma Source**: One defines the activity of the source in Gbq and the radiated rays. The more classical ones are already predefined: Cobalt 60, Iridium 192 & Selenium 75.
- Emission zone: One limits the effective zone of radiation in space with a conical or cylindrical volume. The effective size of the source (anode target with X-rays, radioactive capsule in Gamma) can be assumed as an ideal spot or not, allowing to account for **geometrical unsharpness**.

## Detector

The detectors can be planar or curved. Several ways to define them are possible:

- Simple selection among a list of 16 industrial films of different classes bases on EN584-1 standard.
- Image plates of high sensitivity or high resolution including reinforced screen.
- Definition of all the parameters by the user (gain, material of the sensitive layer, sensitometric curve, experimental data file Gray Level / Incident dose, etc.)

It is possible to take into account the granularity of the film. For any type of film, a filter can be added. A region of interest (ROI) can be used to increase the resolution of the computation at one part of the detector. A MTF curve can be added for any type of detectors and an automatic MTF can be computed by CIVA for image plate detectors.

## Flaws

Several flaws can be inserted in the test piece. They can have different shapes: Planar, spherical, ellipsoidal, trapezoidal, or an arbitrary **3D CAD geometry** as well as calibration holes: Flat bottomed Hole, Side Drilled Hole or Hemispherical Bottomed Hole. Flaws can be made of void, gas or solid. It can be an alloy.

## IQI

A large library of the main **standards IQI** (EN, ASTM, AFNOR, DIN62, and CERL) and **penetrameters** is included in CIVA: Wire (simple, or duplex), Plate with holes, step wedge, etc.



*Some of the IQI available in CIVA*

## Results

Two combined methods (analytical Beer-Lambert & Monte-Carlo) compute **both the direct radiation and the scattered radiation**. The build-up (ratio direct/scattered) is also available in order to estimate the importance of scattering in a given inspection. Scenario of **parametric variations** can be defined.
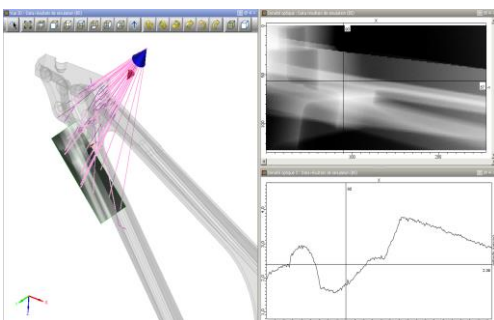


*Result of a simulation of a stiffener radiographic testing: 3D view, photons path, image of the optical density, curves extraction*
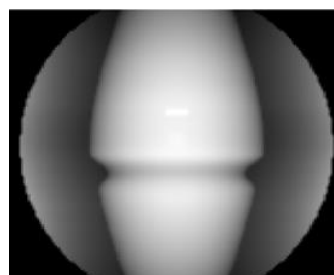
*Result of two different pipes welding*

For Monte Carlo computations, the algorithms benefit from multi-core architectures in order to reduce calculation times. Moreover, if this calculation has been done once, and that user wishes to study the variation of a parameter that does not impact the scattering (variation of the exposure time for instance), the **Monte-Carlo can be re-used** in the new configuration and associated with a new and fast direct computation. CIVA includes a tool that will automatically provide the **estimated number of photons for a good convergence of the Monte-Carlo** simulation.

Users can visualize both the detector response (**optical density or gray levels**) as well as the incident dose in Gray or the deposited energy on the detector in keV. Results are presented as images in the classical CIVA environment as well as curves following selected cross sections, allowing the user **to easily quantify local variations of contrast**. The cursors are dynamically linked to the 3D graphic view and the photons paths are plotted. The thicknesses of materials passed through are identified in a table. The images obtained can be exported in the Tiff or raw format

**POD calculations** (Probability Of Detection) are also available in RT, based on the accounting of uncertain input parameters.

Post-processing capabilities are offered to the user who can **quickly re-calculate** the activity of the gamma source, the intensity of the X-ray source, or the relevant exposure time necessary to reach a **targeted optical density**. In the same way, the optical density can be quickly recalculated if these 3 parameters change.

Some **detectability criteria** based on the smallest surface interpretable by the eye have been implemented. This criterion will help the user to predict the **flaw detectability**. The detectability analysis is available for any simulations in CIVA RT.

<p style="text-align:center"><strong>Discover more about the CIVA RT module at</strong></p>

<p style="text-align:center"><strong><a href="http://www.extende.com/radiographic-testing-with-civa">http://www.extende.com/radiographic-testing-with-civa</a></strong></p>

# CT SIMULATION

The CT module proposes the same interface and same capabilities as the RT module in terms of:
- Specimens
- Sources (X or gamma sources)
- Detectors
- Flaws
- Computation options : simulation of direct and scattered radiation

## Specific Items

The items specific to Computed Tomography are:
- Positioning
- Tomographic scanning
- 3D reconstruction
- Import of experimental data
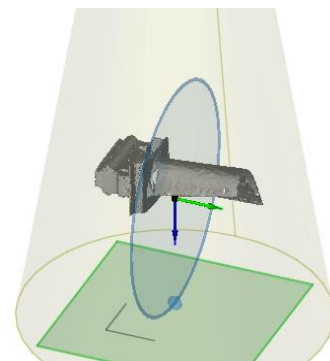


### Positioning

A positioning option allows the user to define the {detector-source} positioning system.
The user can enter the source-axis distance and detector axis distance in a semi-automatic way. Specific misalignment options complete the positioning options. One **can define an offset** of the source and/or the detector versus the specimen to be inspected.

## Tomographic scanning

As the part geometry is fixed in CIVA, the X-ray tube and detector rotates around the specimen. An arbitrary number of steps and shot positions can be defined. Then, CIVA will run the RT simulation for all the projections.

## Results

### *Results for each projection:*

X-ray slice data is generated for each position and the corresponding results can be displayed. Those results are identical to the RT module and depend on the detector and the computation options. All the analysis tools within CIVA RT are also available in CIVA Tomography.

### *CT data import*

The CIVA 11 version allows to **import computed tomography experimental results** from acquisition data. Different acquisition format are already available. If your format does not fit with CIVA import data tool, it is possible from some specific developments to ask to integrate this format thanks to plugins.

### *3D reconstruction:*

Once the scan data has been acquired, the data must be processed using an algorithm of tomographic reconstruction, which produces a series of cross-sectional images. The algorithms used in the current release of CIVA are the **FDK algorithm** (Feldkamp, Davis and Kress) and **PIXTV**.
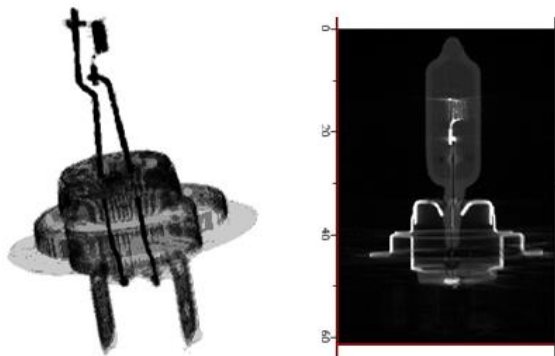


Once the processing is finished, a new analysis page opens with the 3D reconstructed specimen. The 3D view available in CIVA shows the component in 3D dimensions. Many tools are then available to represent the reconstructed component: Display of the **iso surfaces**, **volume rendering**, etc.

On top of this, the user has the ability to see the different 2D sections and grab the different planes. All the sections and the 3D reconstructed view are linked together, by **moving one cursor** in one view, **all the other analysis pages are refreshed** in real time for a better interpretation of the results.

**Discover more about the CIVA CT module at**

**http://www.extende.com/computed-tomography-with-civa**