CIVA 11

EXTEND-E
CIVA

CIVA N·D·E | 11

The simulation platform for NDE

New capabilities: CIVA 10 introduced 3D CAD complex homogeneous component geometries in CIVA. With CIVA 11, **3D CAD heterogeneous specimens** are now available in CIVA UT and CIVA RT-CT, thus greatly expanding the potential applications of CIVA: Assembled structures, welds in complex components, cladded 3D geometries, accounting for change of acoustic properties due to heat-treatments, simulation with multiple objects allowing considering some **backscattering phenomena** in RT, etc. The limits are just your ideas!

In ET, a new axisymmetrical tool replaces the former Multiple Winding module and increases the capabilities as it allows simulating some defect response configurations in **tube transition zones** with its tube sheet (heat exchangers), or tubes with an irregular profile defined by a 2D CAD sketch. Regarding tubes, the electromagnetic field can now also be calculated and displayed in cylindrical geometries in the CIVA ET Field Computation module. Complex shape coils, automated flaw meshing… are just a few of the new features of CIVA ET.

In RT-CT, **image plate detectors are now available** bringing CIVA significantly into the world of **Digital Radiography!** Numerous new probes and sensors are also proposed to the UT and ET users: **EMAT probes** can now be simulated based on a coupling between CIVA UT and CIVA ET (non ferromagnetic materials). In UT, advanced **custom UT phased-array probes** joins the CIVA library, and come together with a new intuitive tool for phased array sequences definition. In ET, a set of new shapes of coils are now available (D-coil, spiral, meander, racetrack, etc.).

In GWT, CIVA 11 allows to account not only for flaws perpendicular to the waveguide but also for some **geometrical discontinuities** (such as weld, a varying diameter, a groove or a junction between straight parts), for the prediction of geometrical echoes in addition to the flaw echo. Modes and fields computations can now be performed on specimen having a 2D CAD cross section, such as **rails**. As in CIVA UT, CIVA GWT 11 is now able **to compute delay laws** in order to focus guided waves in a pipe. The pipe can also be considered as filled with a fluid.

Introduced with CIVA 10 for ET and UT, it is now possible to compute **POD simulations in the RT module** in which some **automatic detectability criteria** have been implemented. The new ability to assess flaw detectability makes the simulation of RT even more useful.

Aiming at getting closer to acquisition systems, one major feature is the ability to define one or several **gates** in CIVA UT as you would do in a real system. CIVA is now compatible with acquisition files from **OMNISCAN® data files** (needs to contact Olympus to update your Olympus dongle), thus benefitting from CIVA's cutting edge viewing and post-processing on your Omniscan® data!   These are really important steps which prepare the fields for future CIVA evolutions. In the same way, in the CT module, you can now import **CT acquisition files**, meaning that you can simulate and **try various 3D reconstructions on real data!**

Better performance and more precise: Continuous architecture and model improvements can keep account for more and more phenomena while improving accuracy and calculation times.

In the UT module, a major improvement is the implementation of a new model for computation of **specimen echoes**. This permits a **dramatic reduction of the computation time regarding specimen specular echoes** calculation which used to be very long with CIVA 10. This new model also allows computation of **interior specular interface echoes** (in multi-volumes or multi-layers configurations for instance). A new model for defect scattering, "KGTD", allows **calculating at once both specular and diffraction contributions** of a defect echo (while you had to do 2 separate calculations before). In **TOFD**, the **lateral waves computation have been enhanced** to better account for curved interface and shadowing effects and is available in more configurations. The "SOV" exact model has been extended to most of the volumetric flaws (spherical, cylindrical). Finally, a new model has been developed for the calculation of attenuation of noise due to the grain micro-structure. This new

model is both more precise and easier to use as the existing one in CIVA 10.

In ET, a specific model has been implemented to precisely account for **crack-like thin flaws**. Flaws can also be combined to simulate complex flaws or to add cracks at a bore hole. The ET supply system can also be accounted for in the model with the ability to introduce **cable electrical parameters** (by circuit coupling) and to define either a voltage source or a current source.

In RT, the Monte-Carlo has been improved to account for **pair creations**, leading to a better accuracy for high energies, especially for X-Ray accelerators. With the new digital detector model, the model also accounts for the effects of a reinforced screen.

All these improvements come along with a **massive parallelization** of the code on CPUs **allowing users to compute much more in much less time!** Additionally, **calculation times are now predicted** at the beginning of the simulation which should help the user to gain a lot of efficiency when organizing his/her simulation studies.

Even if CIVA still runs on 32 bit computers, it is now definitely advised to move to 64 bit machines to fully benefit from these improvements. This new version can work with the new OS Windows 8 (and is still compatible with Windows 7 and XP)

More User-Friendly: Good software has to be not only powerful but also easy to use. After a big change in CIVA 10, some important efforts are still done in order to make CIVA 11 even more user-friendly.

In CIVA UT, some classical work pieces can now be created automatically in a parametric way such as many **weld profiles** (V, X, J bevels, etc.): you will save a lot of time! Another new tool available in CIVA UT is the capability to automatically find the best location and the best steering angle for a UT probe depending on a given flaw: It can be a really useful feature to help preparing inspection plan! The Signal, Phased-array, and Simulation Settings **panels have been redesigned for an easier use. Analysis features** have been strongly enhanced: **identification of wave modes** on scan views in UT defect response, a tool expected for years by most of the users! Calibration can now be performed and modified in post-processing. Other tools have been created such as a mouse-click distance measurement on images or Depth and Time-of-Flight Cscans, specimen views with volume rendering … tools for TOFD analysis (calibration for depth measurement, hyperbolic cursors).

In CIVA ET, the **mesh of the flaws** is now proposed in an **automated** way, which will simplify a lot the use of this module. The ET analysis environment interface has also been greatly improved and completed with new tools. Still in ET, **lift-off signal curves** are now available directly, a very useful feature that was missing before! **Frequency response curves** can also be simulated.

In RT, the user can now **target an optical density** to quickly find out the relevant exposure time as an output.

POD and parametric variation features have been enhanced with a new way of defining uncertainties and variations. The POD page has also been redesigned to offer more features like direct data selection and graphical statistical tests.

Finally, **CIVA ATHENA2D module is integrated in the same environment** for an easier interoperability with CIVA UT.

HARDWARE & SOFTWARE REQUIREMENTS

Standard configuration*:
- o 64 bits OS   == Windows 7 / Windows 8
- o Dual core
- o Ram   >= 4 Gb
- o Hard Disk   >= 250 Gb
- o Graphic Resolution == 1280 x 1024 or 1900x1200
- o DVD ROM
- o USB port for Hardware dongle (Software key will be proposed by default)

*Windows 7 32bits and Windows XP OS are supported (with a minimum of 2 Gb of RAM) **but 64bits OS is strongly advised**. Some failure may happen with calculations performed on these OS due to a lack of available memory.*

Optimized configuration:
- o 64 bits OS   == Windows 7 / Windows 8
- o Quad /Octo core
- o Ram   >= 8 Gb
- o Hard Disk   >= 250 Gb
- o Graphic Resolution == 1280 x 1024 or 1900x1200
- o DVD ROM
- o USB port for Hardware dongle (Software key will be proposed by default)
- o GPU Graphic Processor for computation == GTX580 or Tesla2070 (useful for CT simulation only)

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.
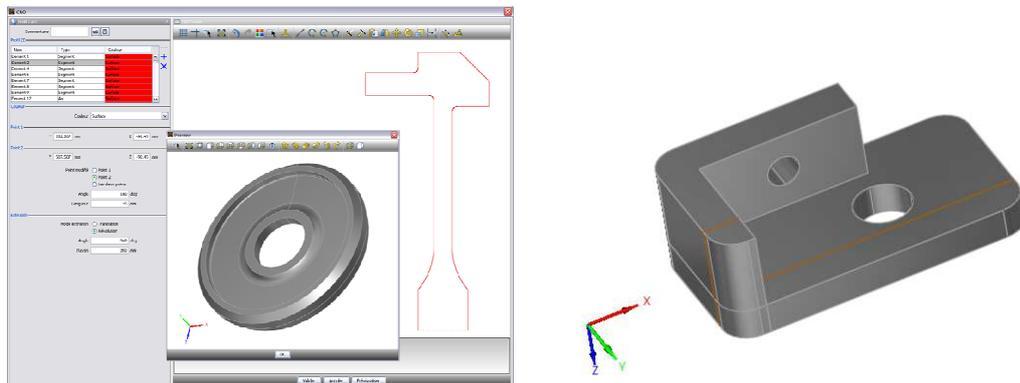
CAD geometries

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

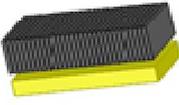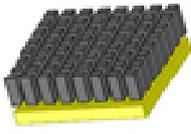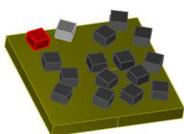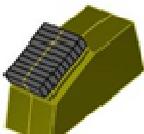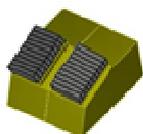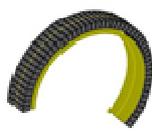A wide range of UT probes (standard and advanced designs) can be handled:

- Single element, dual element, **Phased-array** (see Phased Arrays section), **TOFD**, Tandem probes or **EMAT**
- 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
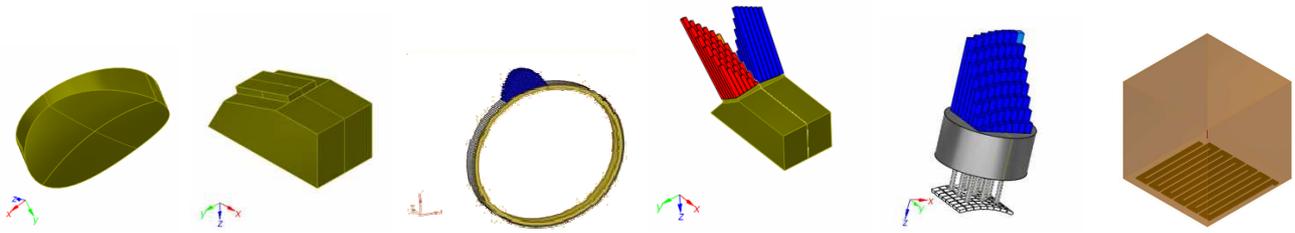
Phased array Settings

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.
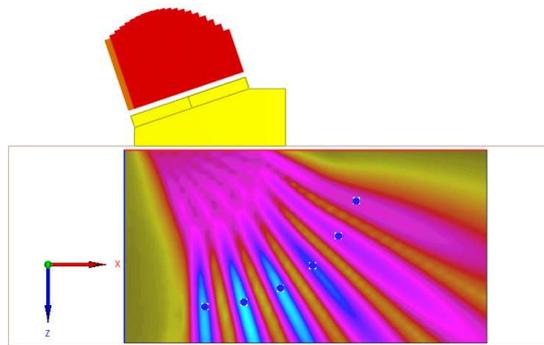

Beam with multiple shots PA probe

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.
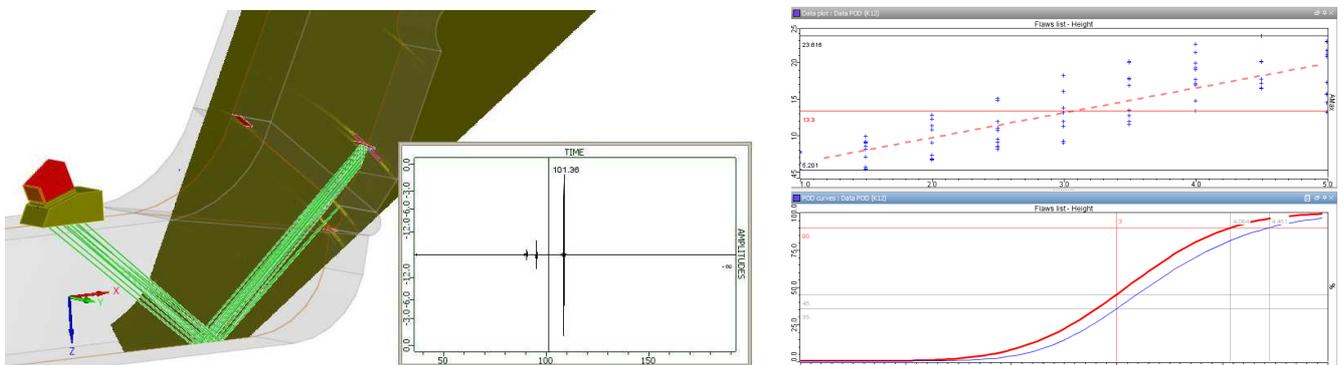

*Inspection simulation results: S-Scan, A-Scan, POD curve, etc.*

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. Results can be calibrated versus a reference flaw in a block. Time Corrected Gain can be also applied from DAC curves.

Acquisition Gates can be defined a priori or a posteriori. A **mode identification tool** allows identifying the different modes that contributes to an echo. Amplitude or Distance measurement tools are included.
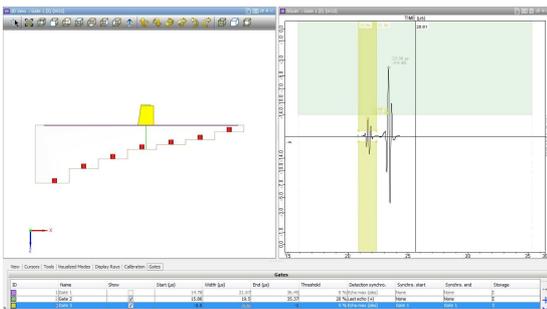
Acquisition gate definition
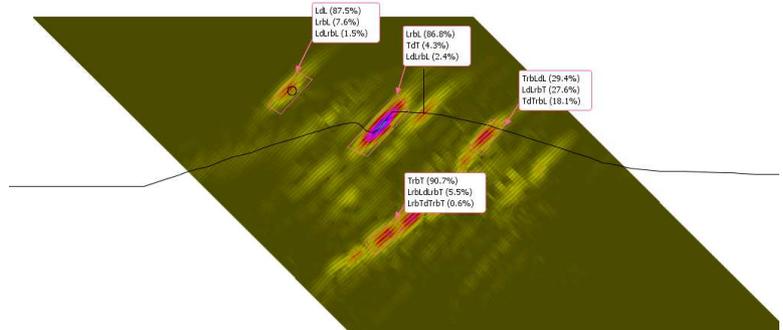
Mode identification tool

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.

The graphical interface can be customized and this customization can be saved for future use.

In addition to simulation results, CIVA can import and post-process real acquisition **data files from Omniscan**® (needs Olympus dongle) and **M2M** Phased-array systems. All results can be exported in ASCII files (A-Scan, C-Scan, POD curve, etc.).

The software also offers a wide range of signal processing methods, some are classical (filters, etc.), others are more sophisticated (wavelets transforms, deconvolution methods, Split Spectrum). A Segmentation tool allows 3D grouping of signals, managing of these groups and report export to spreadsheets. The different phases of analysis (limitations, signal processing, etc.) are saved and settings can be edited. Thus, for the analysis of large files, extracting or limiting data to interested areas is possible, saved and can be annotated (titles, observations…).

**Discover more about the UT module at**

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

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.
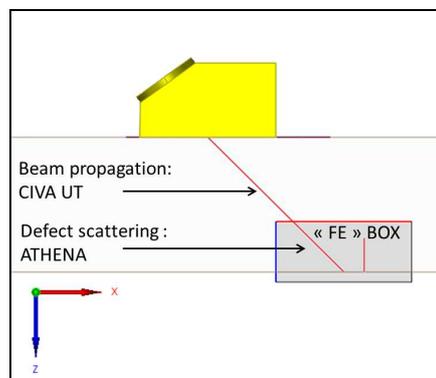

Simulation Examples: Take into account all phenomena

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
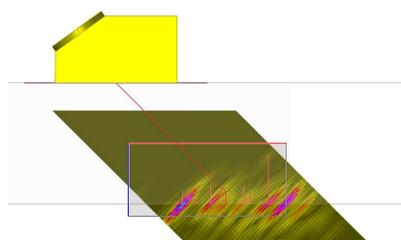
Network of flaws (multiple scattering)
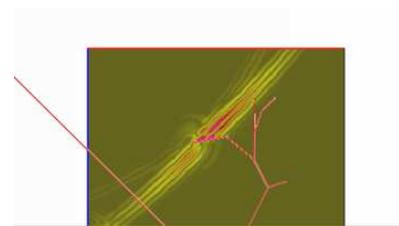
Complex flaws and creeping waves generated

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).
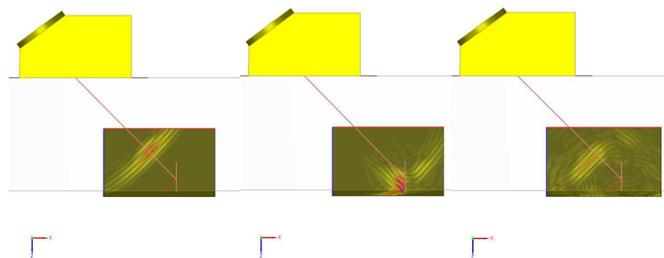
Snapshots of the beam/flaw interaction vs time

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.
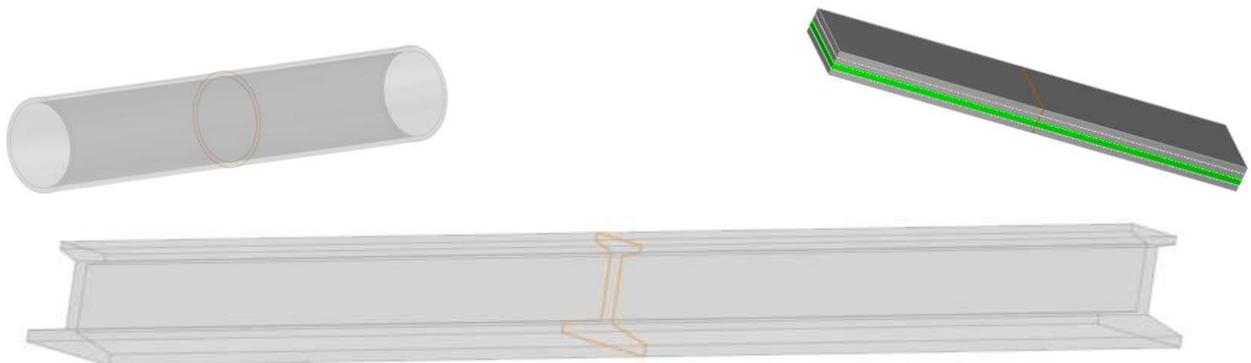
PROBES

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

- Contact (with or without wedge)
- Single element or phased-array probes (see Phased Arrays section)
- 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)
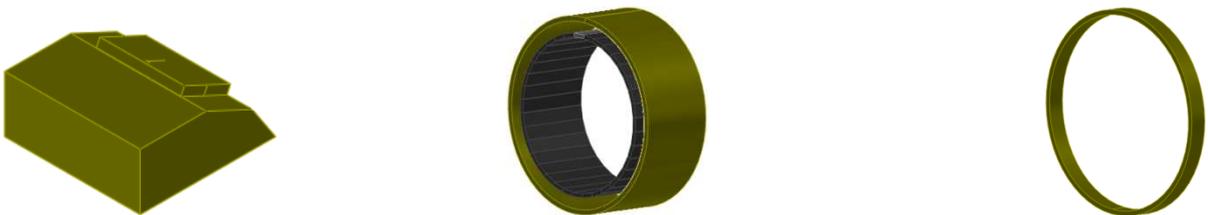

SPECIMEN

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
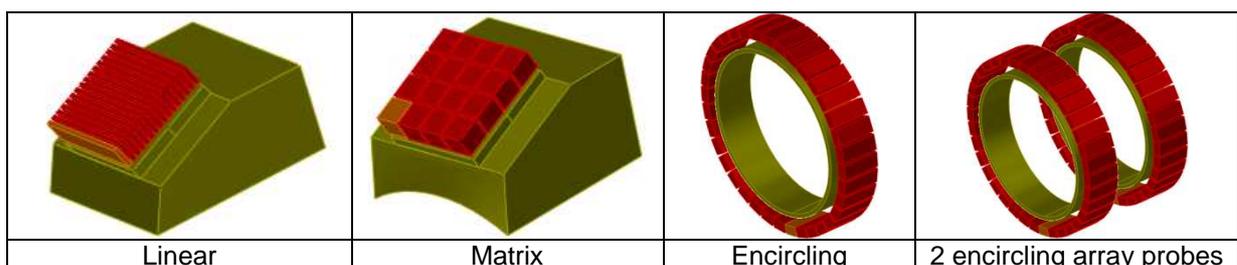
- Independent definition of emitting or receiving elements
- Variable aperture at emission or reception, for size or position

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).
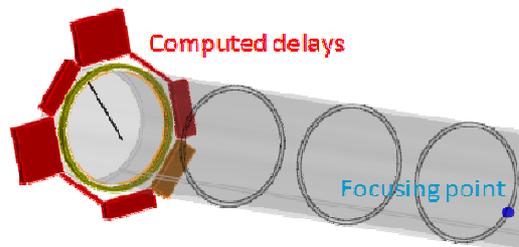

FLAWS

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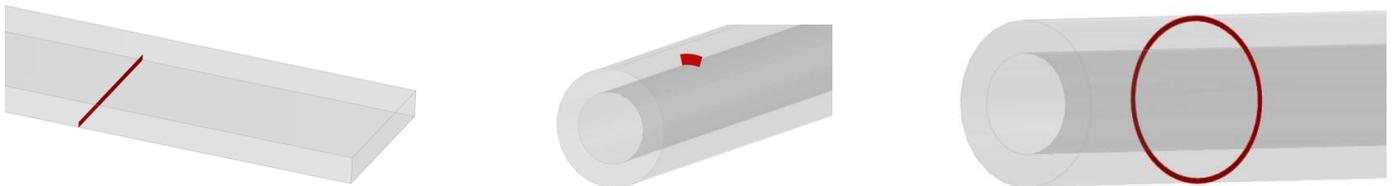
Since CIVA 11 GWT, 2D geometrical discontinuities, such as a weld, a groove, a transition (varying diameter) or a junction between straight parts, can be handled for echoes prediction. One or several axisymmetrical flaws can then be accounted for in this discontinuity.
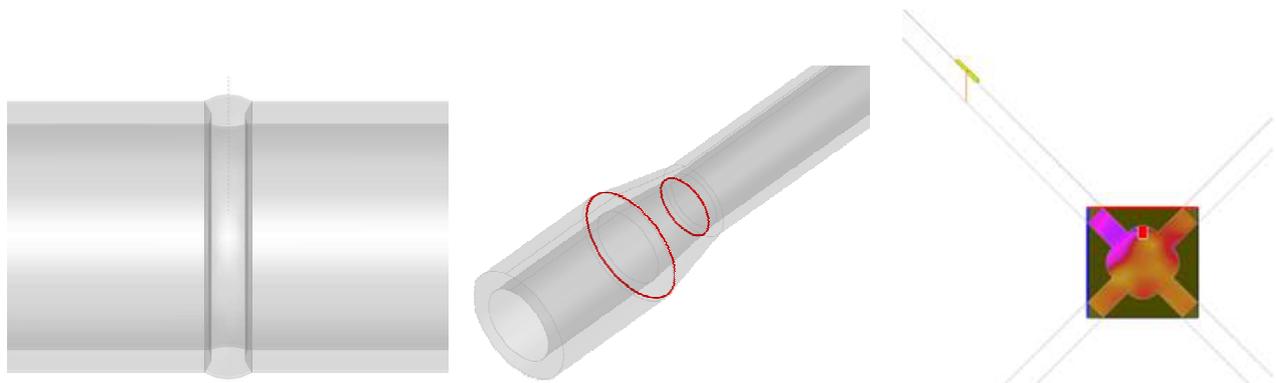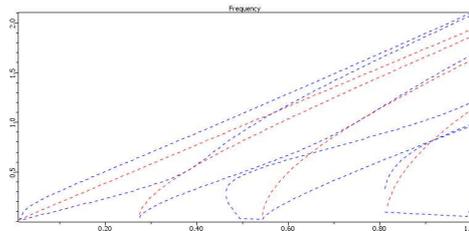
RESULTS

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.
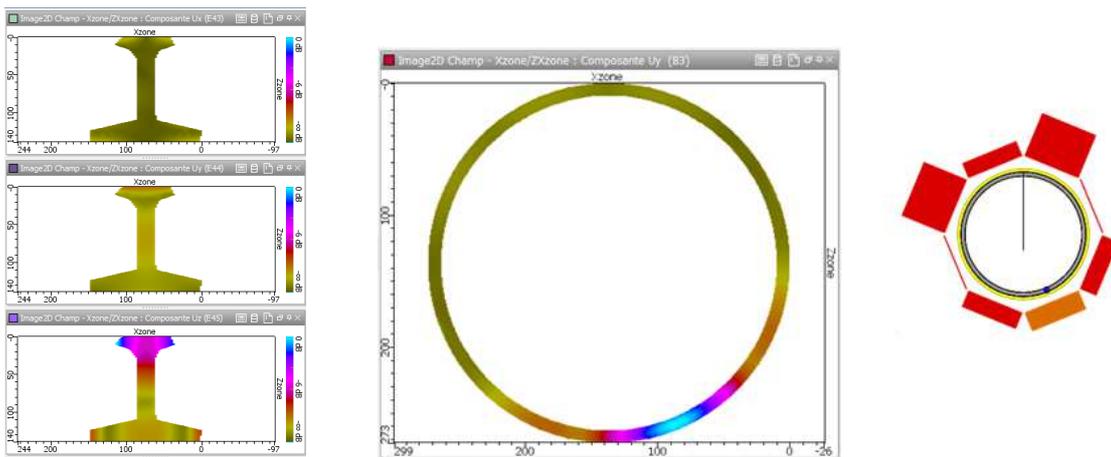
Defect response

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.
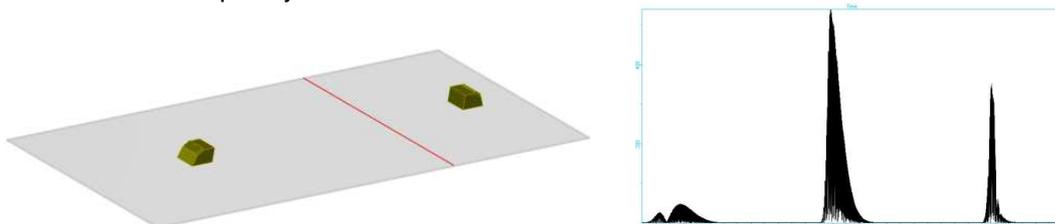
Discover more about the CIVA GWT module at

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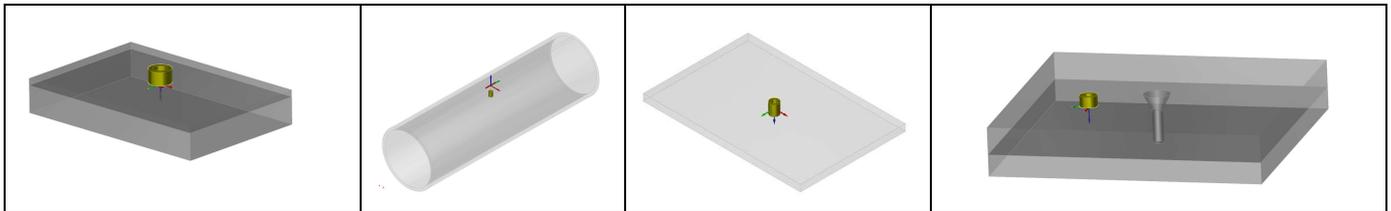
Some of the available component geometries: Cylinder, Plate, Multilayers plate, Fastened plate

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).
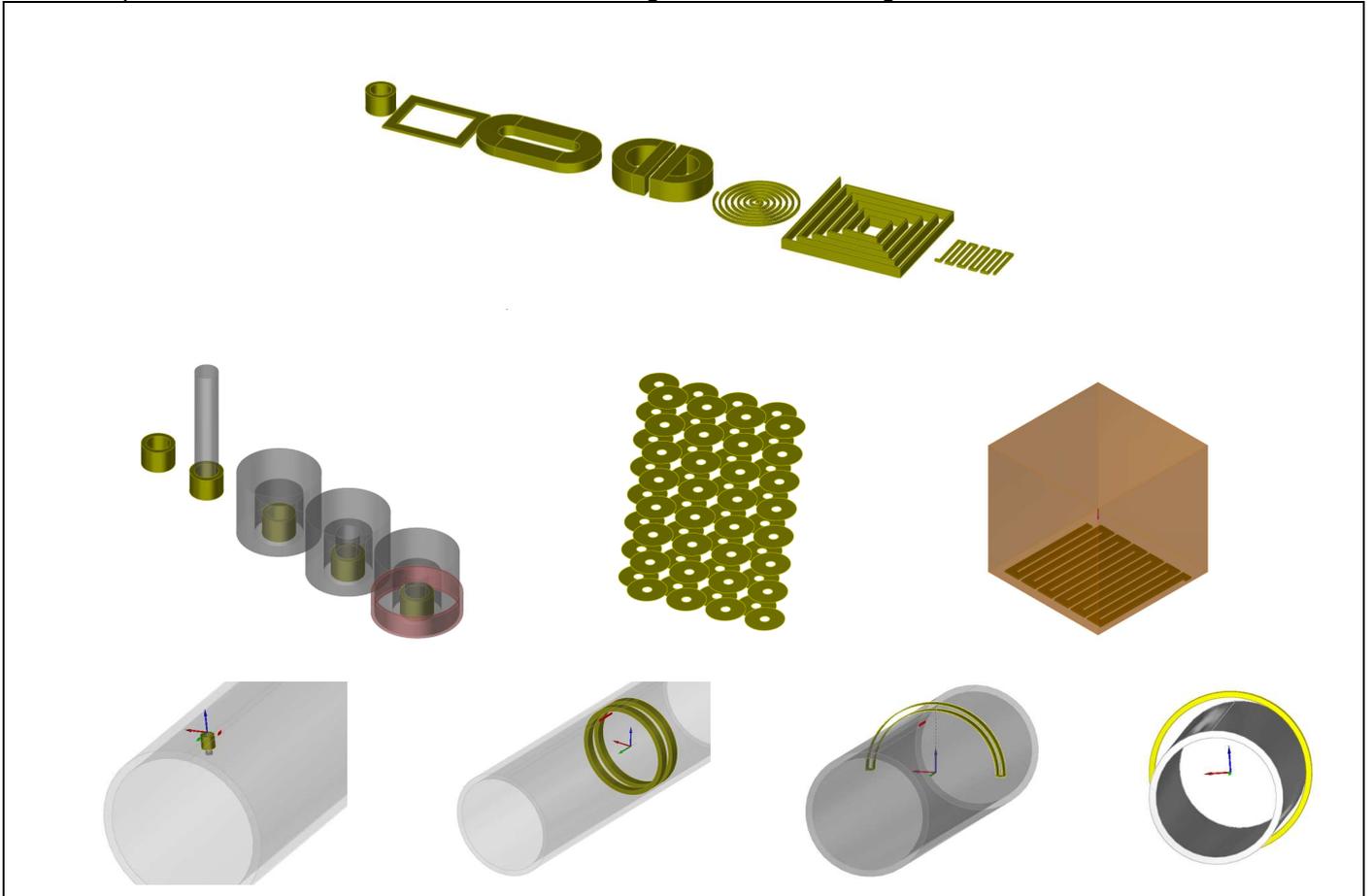
Probes

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**

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.
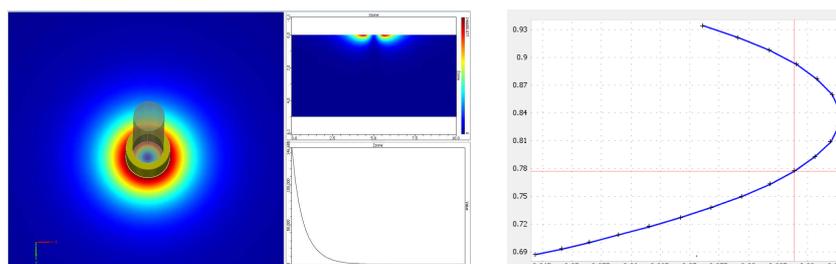
Some results available in the Field Computation module: Eddy Current induced in the specimen, Frequency response of the sensor (normalized impedance diagram)
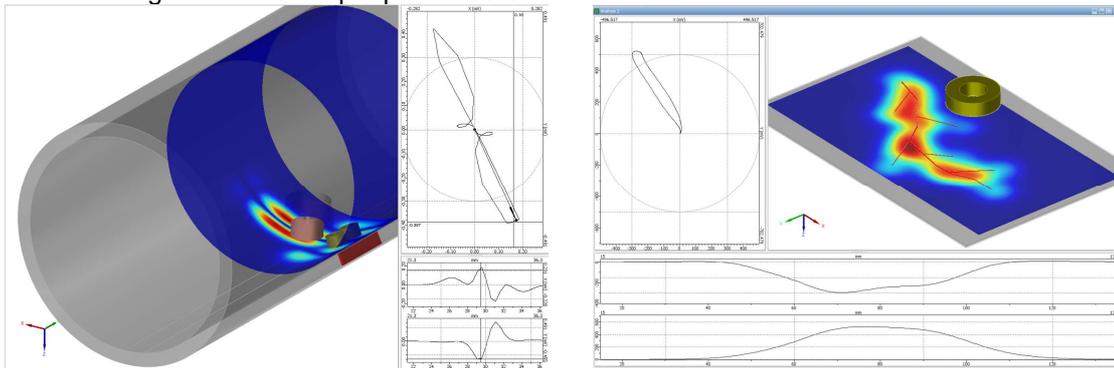
Inspection simulation 3D

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.
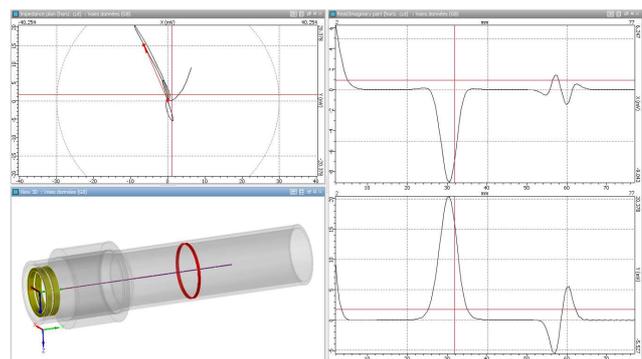
Inspection of a tube transition zone in a tube exchanger

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.
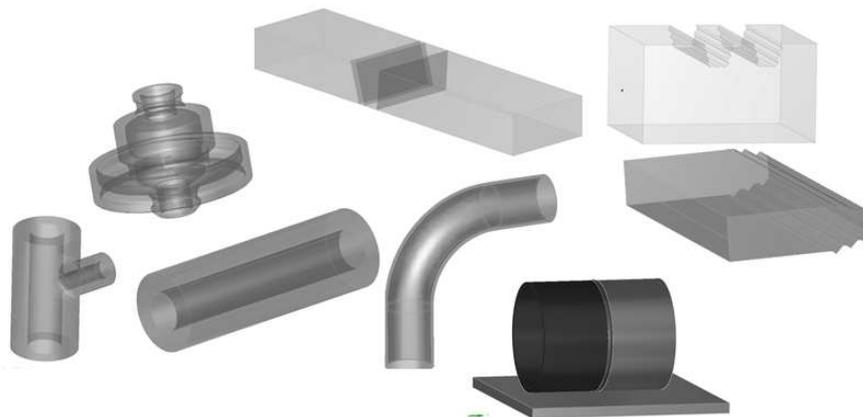
Specimen

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 :
  - **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
  - **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, 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.
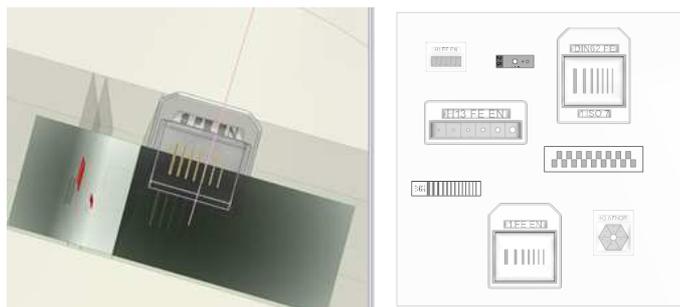

Some of the IQI available in CIVA

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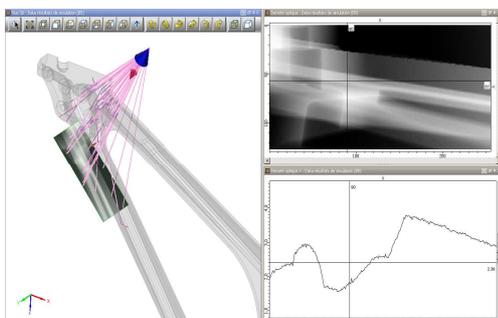
Result of a simulation of a stiffener radiographic testing: 3D view, photons path, image of the optical density, curves extraction
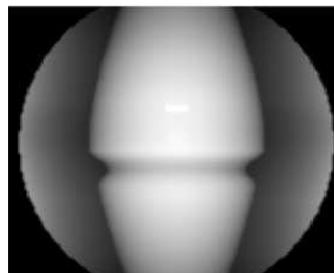
Result of two different pipes welding

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.

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 now available in RT, based on the accounting of uncertain input parameters.

Since CIVA 11, post-processing capabilities have been 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 has also been implemented. This criterion will help the user to define the **flaw detectability**.

Discover more about the CIVA RT module at

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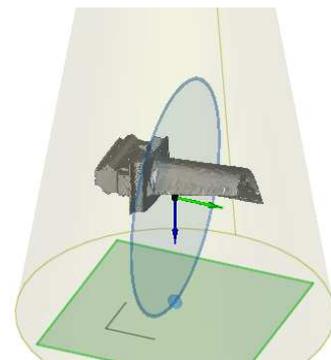
Positioning

A positioning option allows the user to define the {detector-source} positioning system.
The user can now 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**.
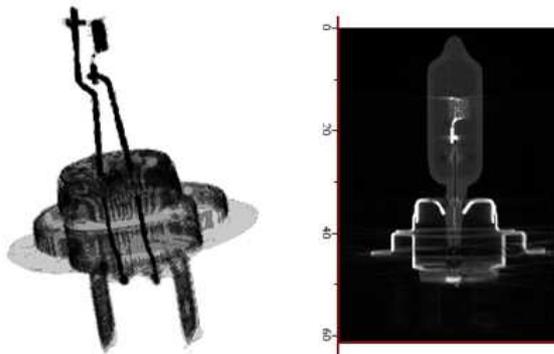
Once the processing is finished, a new analysis page opens with the 3D reconstructed specimen. The 3D view available in CIVA shows the component in 3D dimensions. Many tools are then available to represent the reconstructed component: Display of the **iso surfaces**, **volume rendering**, etc.

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/tomographic-testing-with-civa