Working Group COFREND
« Eddy Current NDT modeling »

Benchmarks for validating and improving simulation codes acceptation

cofrend French Society for NDT

Fabrice FOUCHER - *EXTENDE*
Léa MAURICE – *EDF CEIDRE*
Thierry SOLLIER - *Institut de Radioprotection et de Sûreté Nucléaire*
Christophe REBOUD - *CEA, LIST, DISC*
François DENEUVILLE - *Vallourec Research Center France*
Adrien TRILLON - *Vallourec Research Center France*
Pierre THOMAS - *EDF R&D*

EXTENDE CIVA

Why using modeling in NDT ?

- Help for inspection planning and probe design
  - Time and costs savings: less prototypes
  - Improved performance and confirm defect characterization
  - Help with the introduction of innovation
  - Check inspection limitations: Help in designing components
- Expertise
  - Comparison between experimental data and simulation
  - Better understanding of physical phenomena
- Support qualification documentation
  - Fast and easy parametric studies
- Visual support during bid proposals & technical discussions with the different interlocutors
  - Illustrate to convince
- Training

Simulation Tools for Eddy Current

Simulation tools

Numerical Finite Elements

Semi-analytical

Examples of software:

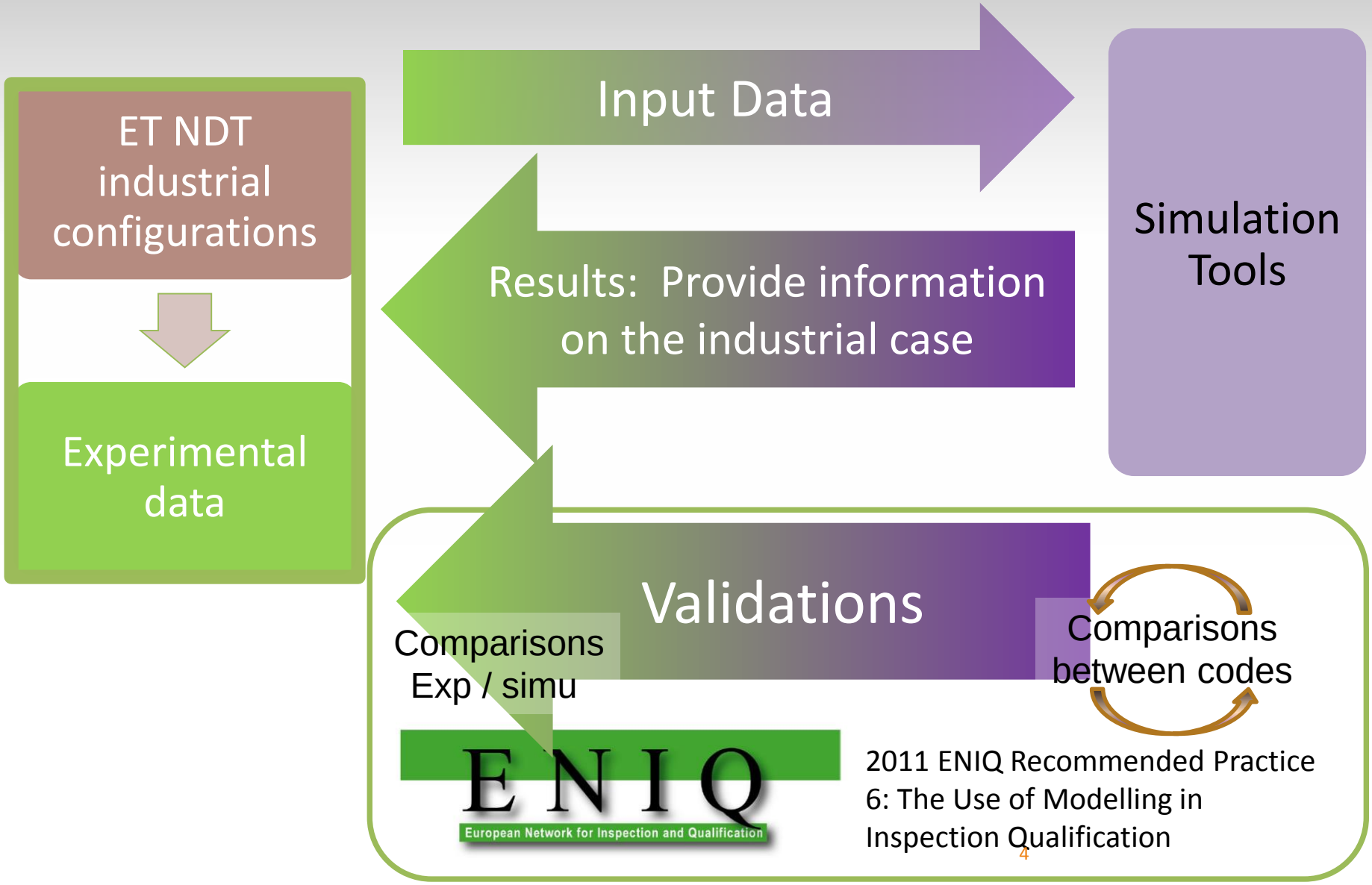
- **Code_Carmel3D**
(current version 2.4.0), developped by LAMEL : collaborative lab between EDF R&D and L2EP (Lille University).
- **Flux3D**
(current version 11.2), developped by CEDRAT and G2ELAB (Grenoble University)
- **Comsol Multiphysics**

Allow to cover a wide scope of configurations

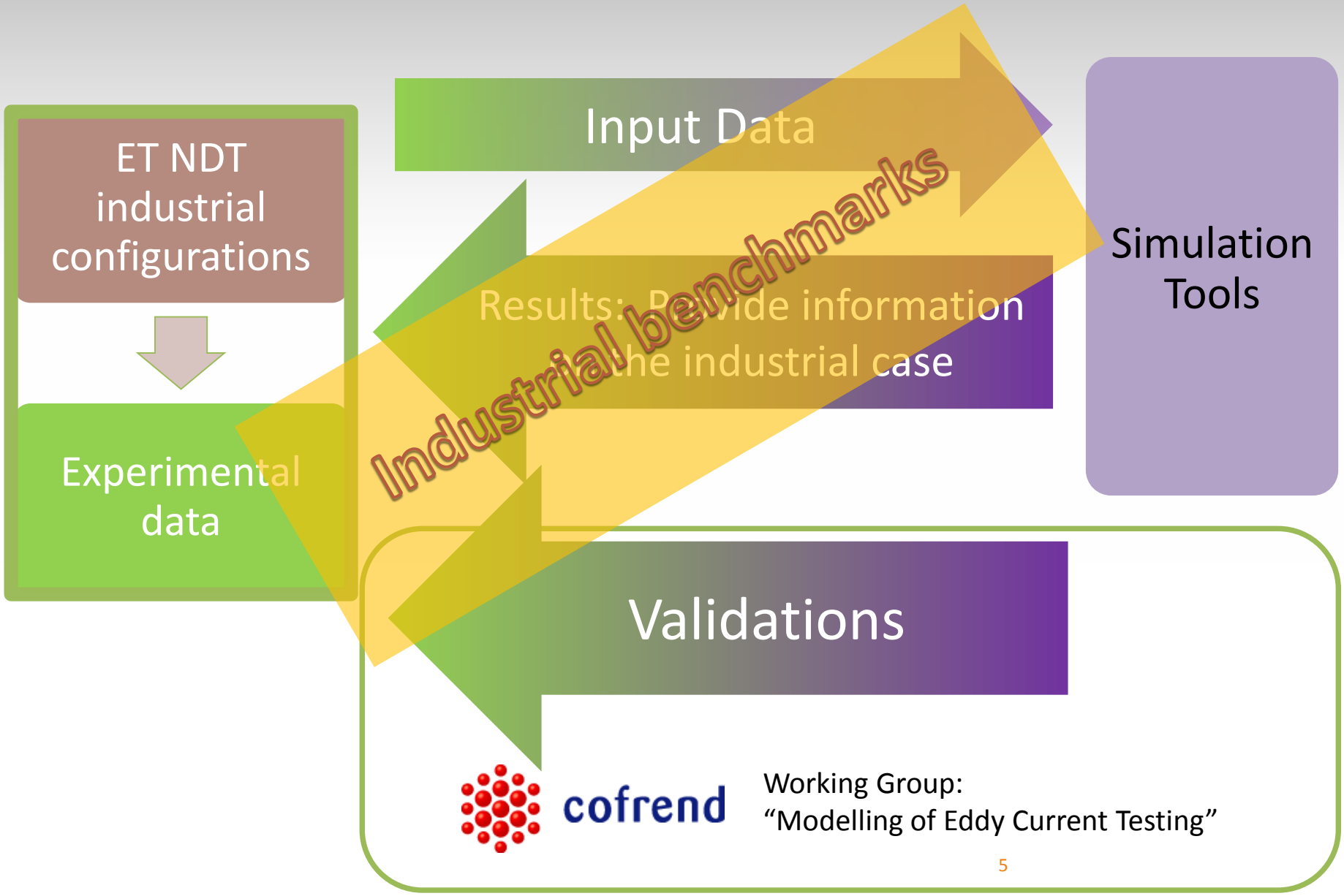
Eddy Current module of **CIVA platform,** developped by CEA & distributed by EXTENDE

More restricted capacities but generally faster and easier to use for non specialists of modeling

Use of simulation in NDE



Use of simulation in NDE



WG « Modelling of Eddy Current Testing»

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Members of the group:

- Industrial end-users :
  VALLOUREC, EDF, AREVA, SNECMA, DASSAULT AVIATION, AIRBUS GROUP,
- Research centers: IRSN (in support to French Safety Authorities), CEA, Supélec/CNRS (L2S, LGEP), IREENA
- Engineering & Consulting : EXTENDE
- NDE system manufacturers: ALPHATEST SYSTEMES

- 3 meeting per year with 8 to 13 participants

Missions of the WG

- Define test cases, provide experimental data and simulation results
- Inform the NDE community of simulation software capabilities

http://www.cofrend.com/controles-non-destructifs/methodes-de-controle/courant-foucault-et/gt-modelisation/

Missions of the WG

- **Define test cases, provide experimental data and simulation results**
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Real industria configurations

- Confidential information

Simplified but representative configuration

- Trials on mock-ups
- Experimental data

Criteria to define benchmarks

- *Realist*
- *Simple*
- *New*
- *Verifiable - Publishable*

Template

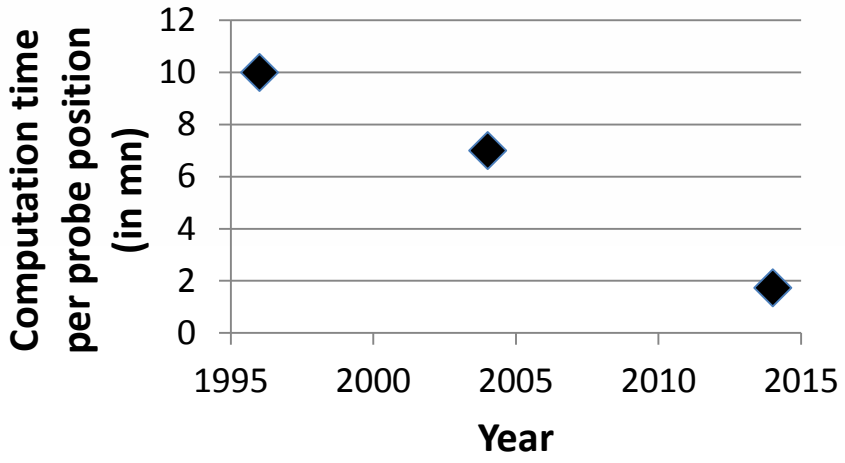
- Defined in 2010
- Support to define input data for each benchmark

Missions of the WG

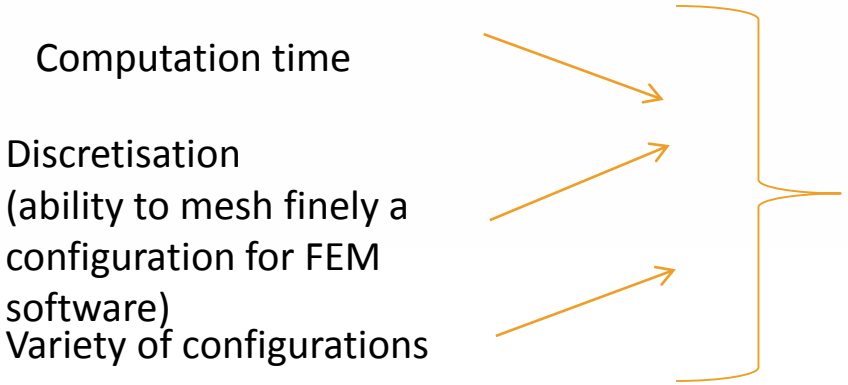
- Define test cases, provide experimental data and simulation results
- **Inform the NDE community of simulation software capabilities**

Evaluation criteria of simulation tools for the user:

- The variety of configurations that can be solved,
- The accuracy of resuts on these configurations,
- The computation times,
- The user interface (GUI) and the necessary numerical expertise required to obtain a good result
- The support service and the evolution of the tool with new releases



Example of calculation time evolution for the benchmark « TEAM workshop 8 » by Finite Element Software



More & more capabilities

→ To answer more complex questions

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“Modelling of Eddy Current Testing”

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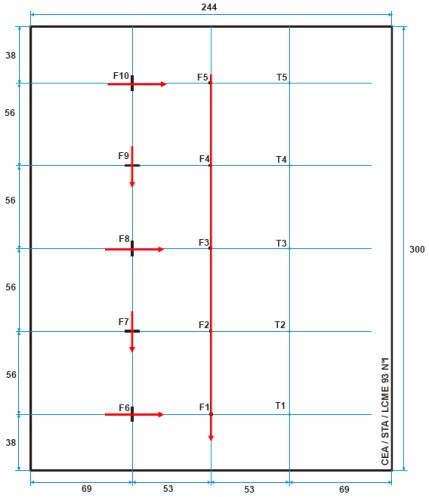
PRESENTATION OF BENCHMARKS

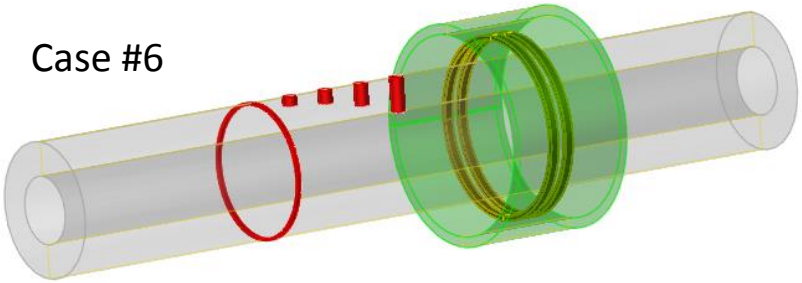
TEST CASES

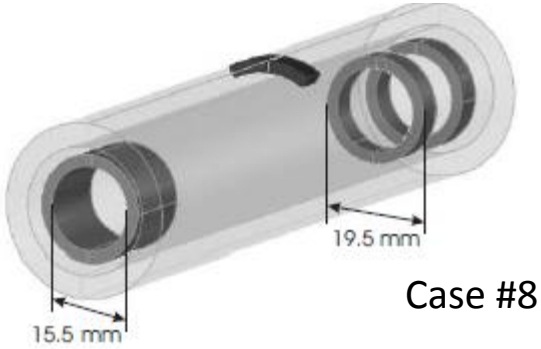
- ❑ Case #2 (EDF - CEA LIST) : *Through wall notches in amagnetic conductive slabs*
- ❑ Case #6 (Vallourec, CEA LIST) : *Encircling coils testing on stainless steel tubes*
- ❑ Case #7 (CEA, SNECMA) : *Model of fatigue cracks by very small flaws in nickel alloy component.*
- ❑ Case #8 (CEA LIST) *: Remote Field Testing*
- ❑ Case #9 (CEA LIST, WMU) *: Bilayer plate with fastener hole*
- ❑ Case #10 (*In progress): multilayers with varying electromagnetic properties*

Case # 2

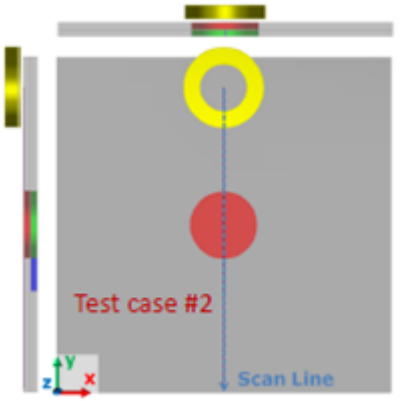


Case #6



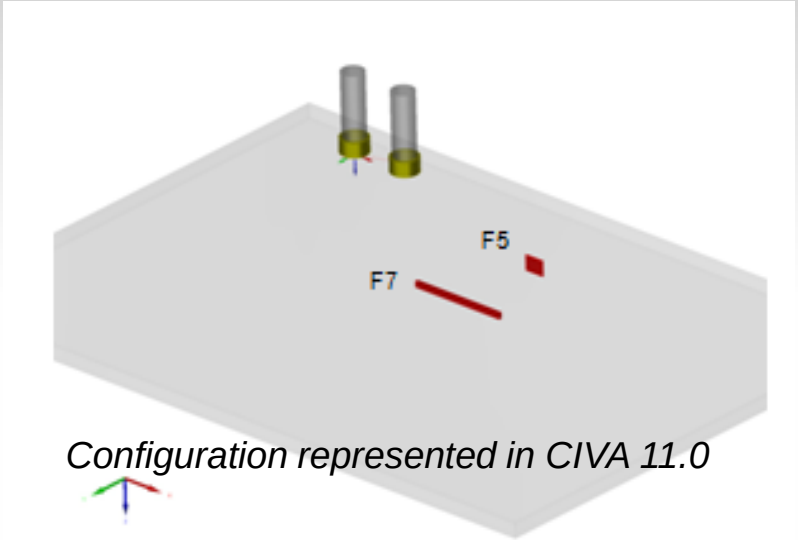


Case #8



Case #9

Test case #2 (EDF - CEA LIST) : Through wall notches in inconel plates



Configuration represented in CIVA 11.0

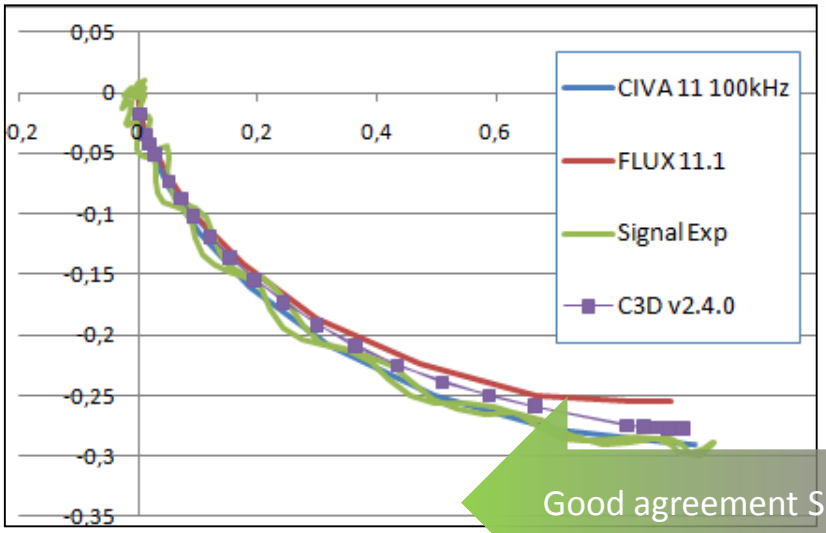
Inspired from nuclear field
(Heat exchangers in INCONEL 600)

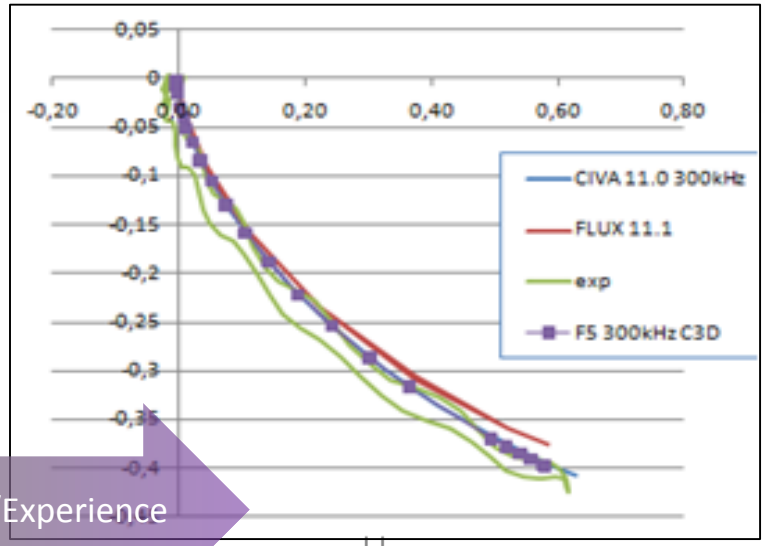
Input data:

Inconel 600 plate, thickness 1,55mm.
Calibration Flaw F7 (10 mm x 0,3 mm x 40%)
Target Flaw F5 (2mm*0.1mm*100%)
Reflexion mode transducer (100kHz & 300kHz)

(Benchmark also defined with absolute mode single coil, communications in pas conferences)

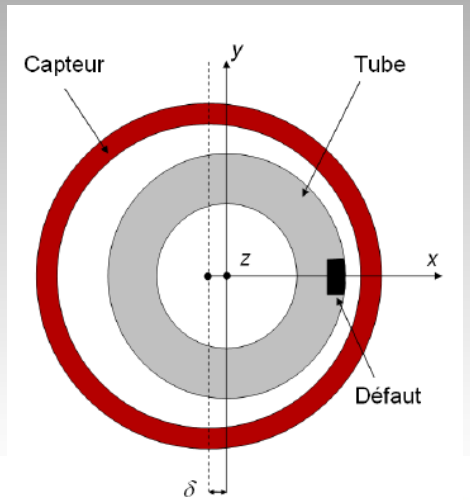
Results obtained on flaw F5 at 100kHz (left) and 300 kHz (right) :





Good agreement Simulation/Experience

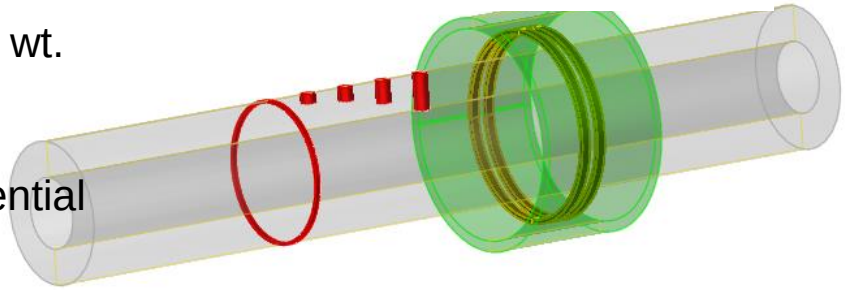
Test case #6 (VALLOUREC)



On line Inspection
Stainless Steel tubes TP304L

Input data:

Tube stainless steel 304 (1,43MS/m), 32mm OD*8mm wt.
FBH Ø 3,5 mm with depths 2mm,3mm, 5mm
& TWH (100%)
Encircling coils : 1 transmitter and 2 receivers in differential mode, frequencies: 3,50 & 100kHz



Results obtained on TWH (calibrated on FBH 3mm depth):

	Ampl. (V)	Diff. Ampl.	Phase (deg.)	Diff. Phase
Experiment	0,98	*Ref.*	84,5	*Ref.*
CIVA 11.0	0,99	0%	84,7	-0,2
FLUX11.1	0,98	0%	86,6	-2,1

Centered

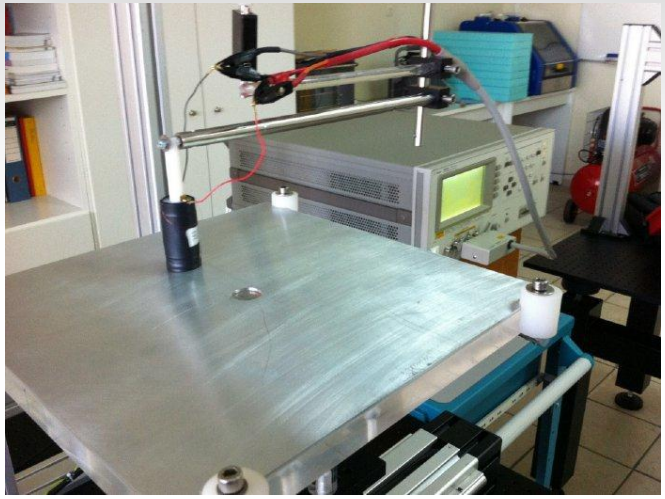
	Ampl. (V)	Diff. Ampl.	Phase (deg.)	Diff. Phase
CIVA 11.0	1,88		90,2	
FLUX11.1	1,91	1,8%	93,2	3

Off-centered *(2mm off centering)*

Test case #9

Aerospace configuration : Fastener hole insp.

(CEA LIST, Western Macedonia Univ.)



Input data:

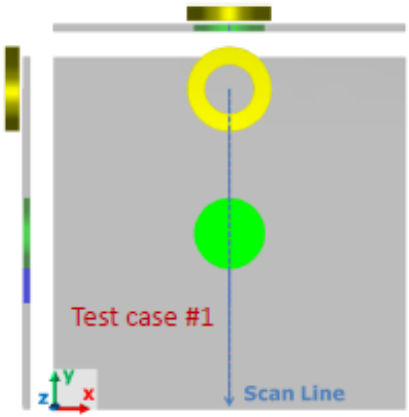
Aluminium plate (17,4MS/m). Simplified version: Wide bore (10mm).

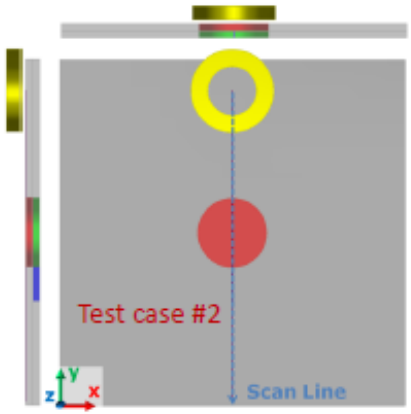
Sensor : Single coil, absolute mode, 1kHz & 5kHz

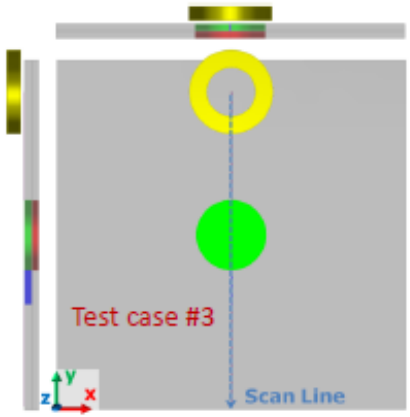
4 configurations:

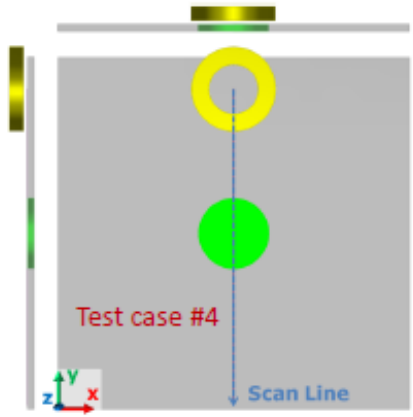
- ✓ #1: One layer with Through Wall notch (9,8mm*0,236 mm)
- ✓ #2: Two layers (interlayer gap 70 μm) with notch on the lower layer
- ✓ #3: Two layers with notch on the upper layer
- ✓ #4: One layer, free flaw

University of Western Macedonia
Department of Mechanical Engineering
Faculty of Engineering









Test case #9

Aerospace configuration : Fastener hole insp.

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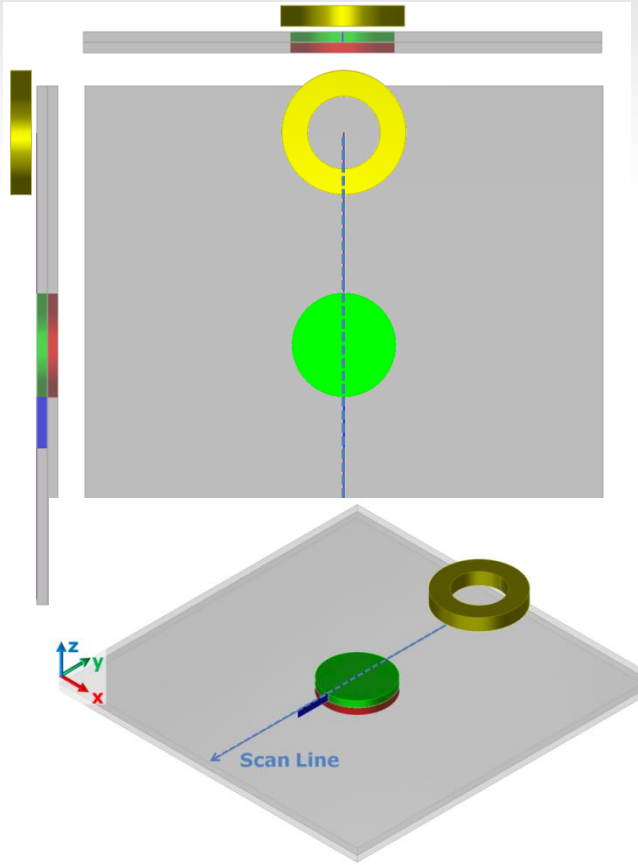
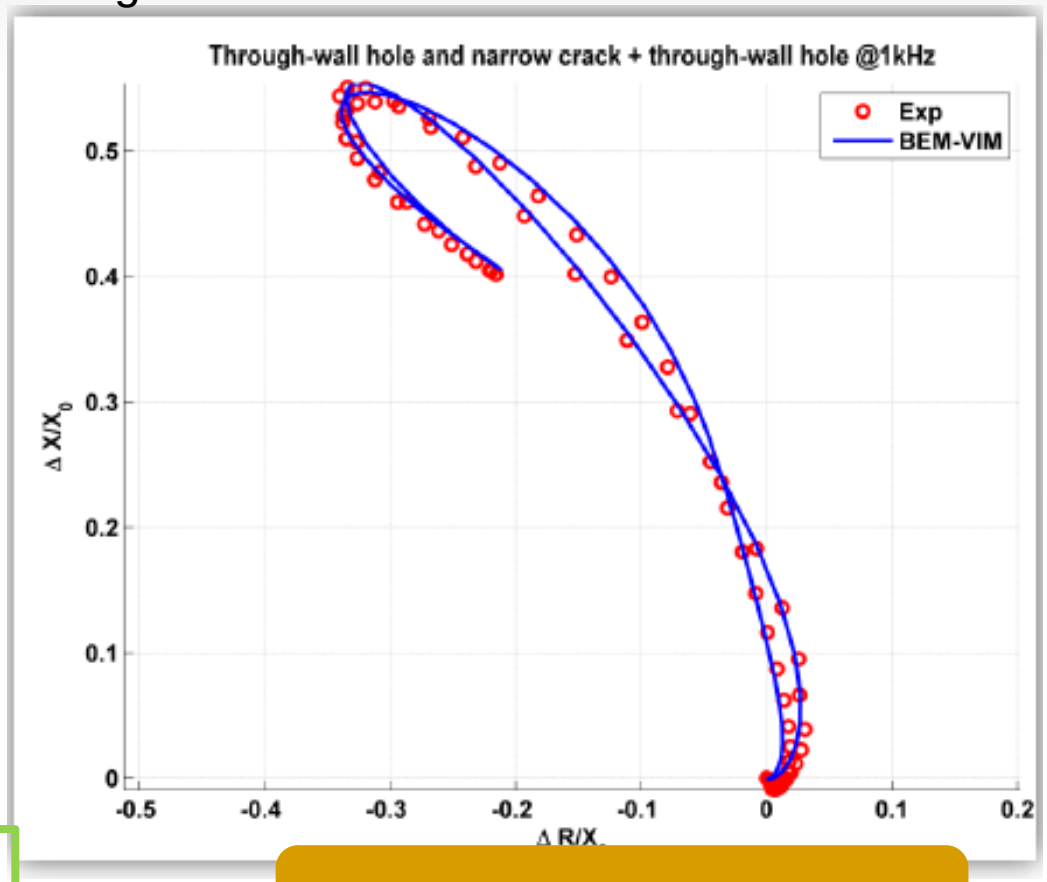


Impedance plane results:

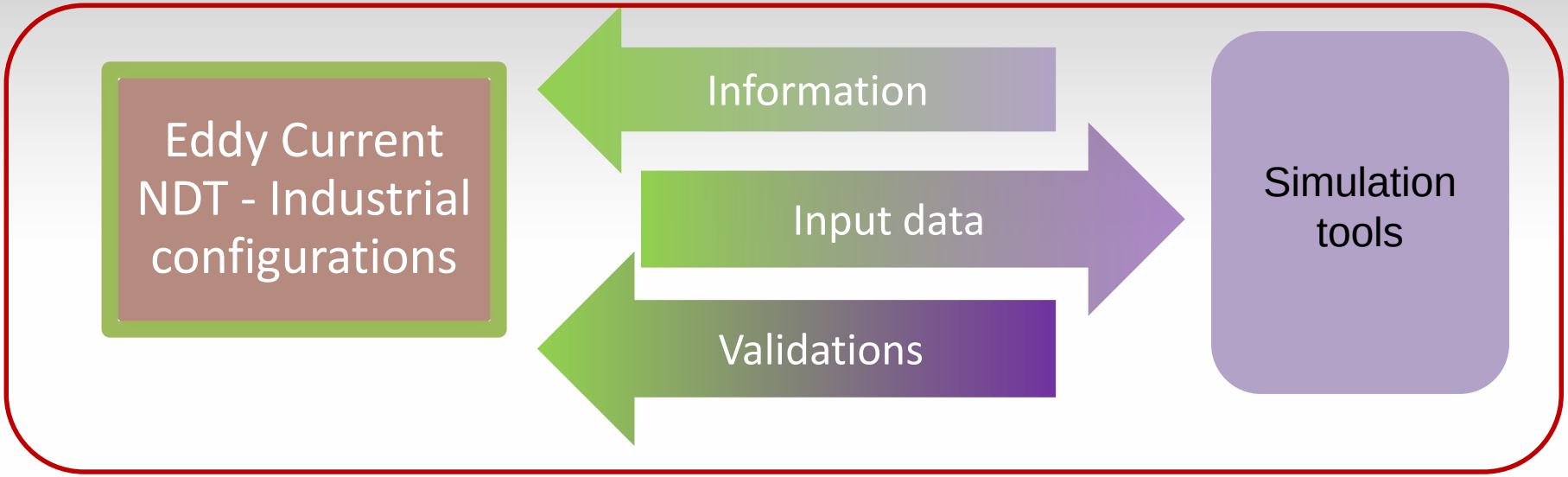
Simulation with CIVA11 & experimental data, configuration #2 à 1kHz



Results from other codes waited for 2014

Presented at QNDE 2013

Conclusion



WG COFREND « Modeling of Eddy Current Testing»

Various industrial sectors	**5 Test-cases defined,** solved or to be solved by simulation codes **1 Test-case to be defined soon**	More to come: http://www.cofrend.com/controles-non-destructifs/methodes-de-controle/courant-foucault-et/gt-modelisation New subjects, new participants, new codes, ….

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Thanks for your attention !

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PRAGUE 2014
October 6 – 10, 2014

EXTENDE CIVA