Automation of simulation supported POD computations with CIVA for power generation industry

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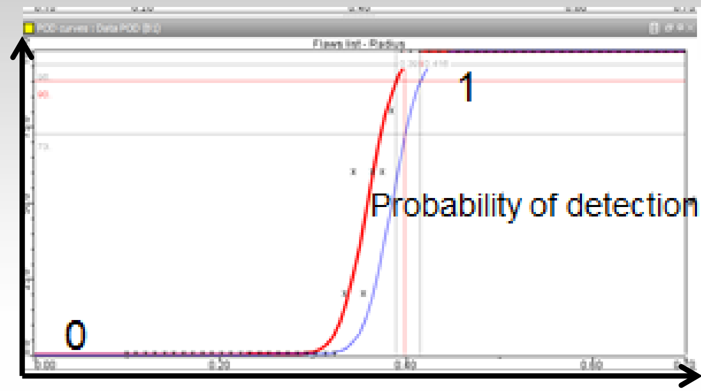
Contents

Context

- Context:
  - UT Inspection at ALSTOM POWER of power plants components after manufacturing
  - Qualification: Demonstrate reliability of testing procedures
  - PoD: Probability of Detection
    - Evaluate the probability to detect relevant indications accounting for the variability of influential parameters:
      - Defects properties (dimensions, orientations, depths)
      - Other parameters (transducers, positionning, refraction angles, human factor, structural noise, etc.)
    - Mostly done experimentally with mock-ups

Context and PoD methodologies

- Different approaches for PoD
  - In aerospace:
    Following military HDBK 1823-A
    Berens Approach

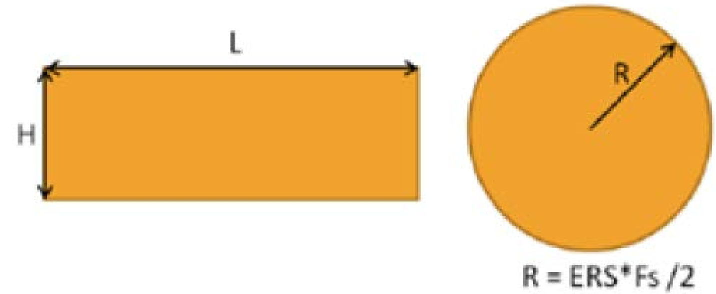


  - Oil & Gas industry: following DNV standards & recommendations
- Approach used by ALSTOM
  - For one type of flaw and for the whole set of transducers used in the inspection:

$$\text{POD} = \frac{\text{Number of detected flaws}}{\text{Number of existing flaws in the mock-up}}$$

  - With the detection criteria:

$$\pi\,(ERS * f_s/2)^2 > L * H$$



Comparison of actual flaw surface and ERS value of the signal

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Why Simulating POD ?

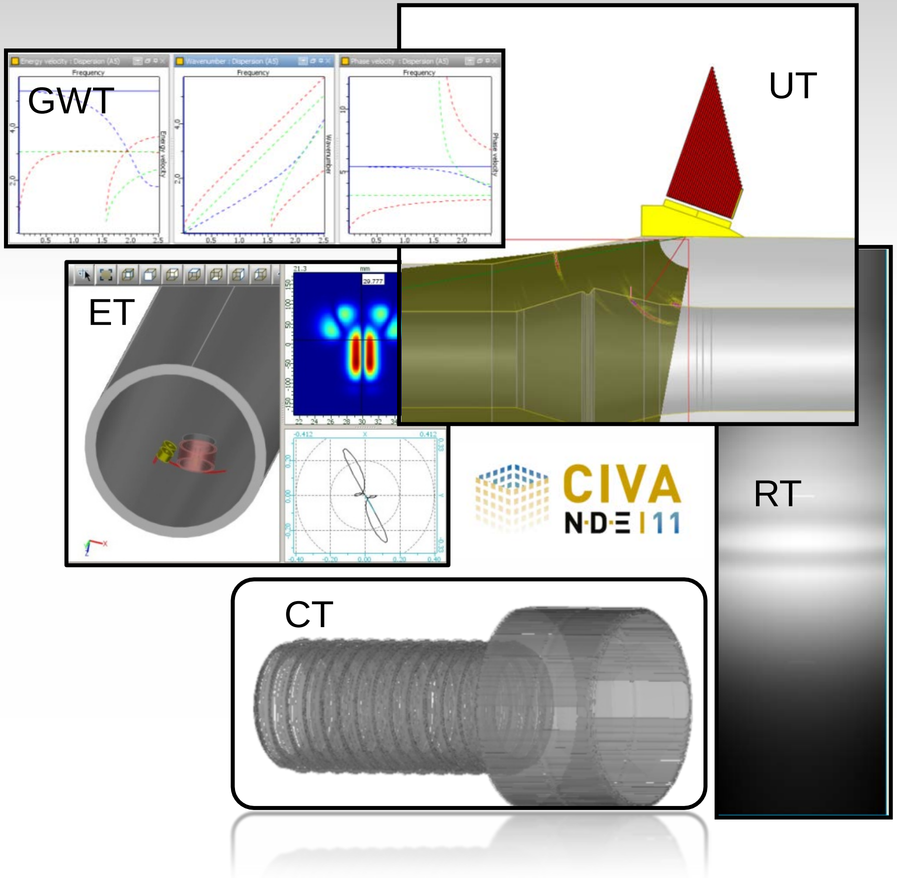
- Building a POD : Many mock-ups, often destroyed after testing to have references, many acquisitions, analysis, etc.
- Reliable POD : Mock-ups correctly designed (influential parameters in their variation domain).

Very costly process

- Benefits of numerical simulation of POD:
  - Find most influential parameters
  - Optimize design of experiment: Find the relevant variation domain of relevant influential parameters
  - Complete experimental POD Curve with missing values to increase reliability
- …at a lower cost than a fully experimental approach

CIVA simulation software

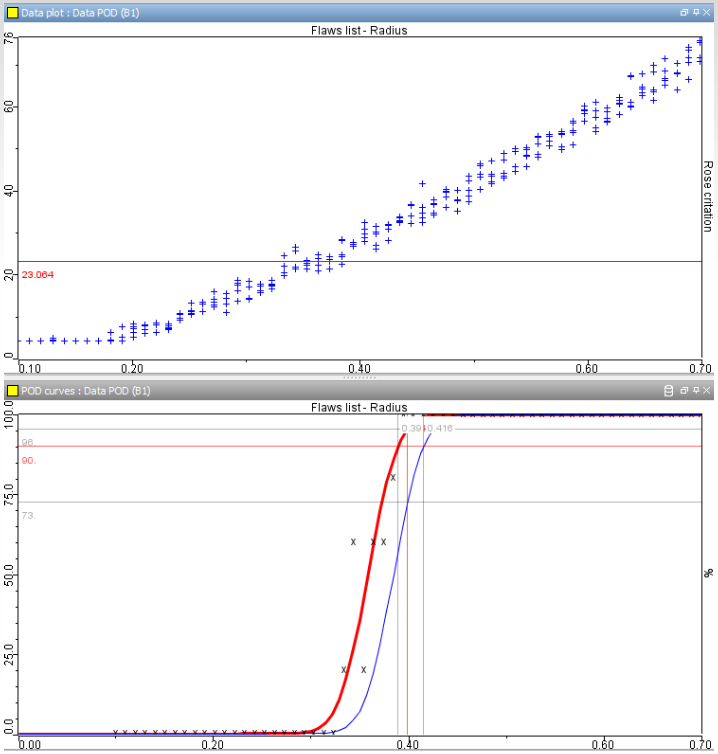
- Simulation software: CIVA
- Dedicated NDE modeling tool
- Multi-techniques :
  - UT
  - GWT
  - ET
  - RT
  - CT
- Semi-analytical models
  (quite fast computation times)
- Developped by CEA
  (French Atomic Energy commission: Research center)
- Distributed by EXTENDE worldwide
- Used by more than 200 companies worldwide
- Version 11.0 released in July 2013



Simulating POD in CIVA

- POD module available in CIVA

- Module based on Berens model used in aerospace
  (and Cheng Method for lower confidence bound).



- ALSTOM applies different standards:
  - CIVA provides most of the tools necessary to simulate Alstom PoD procedures
  - But not directly in the convenient format

Challenges of POD data required by ALSTOM

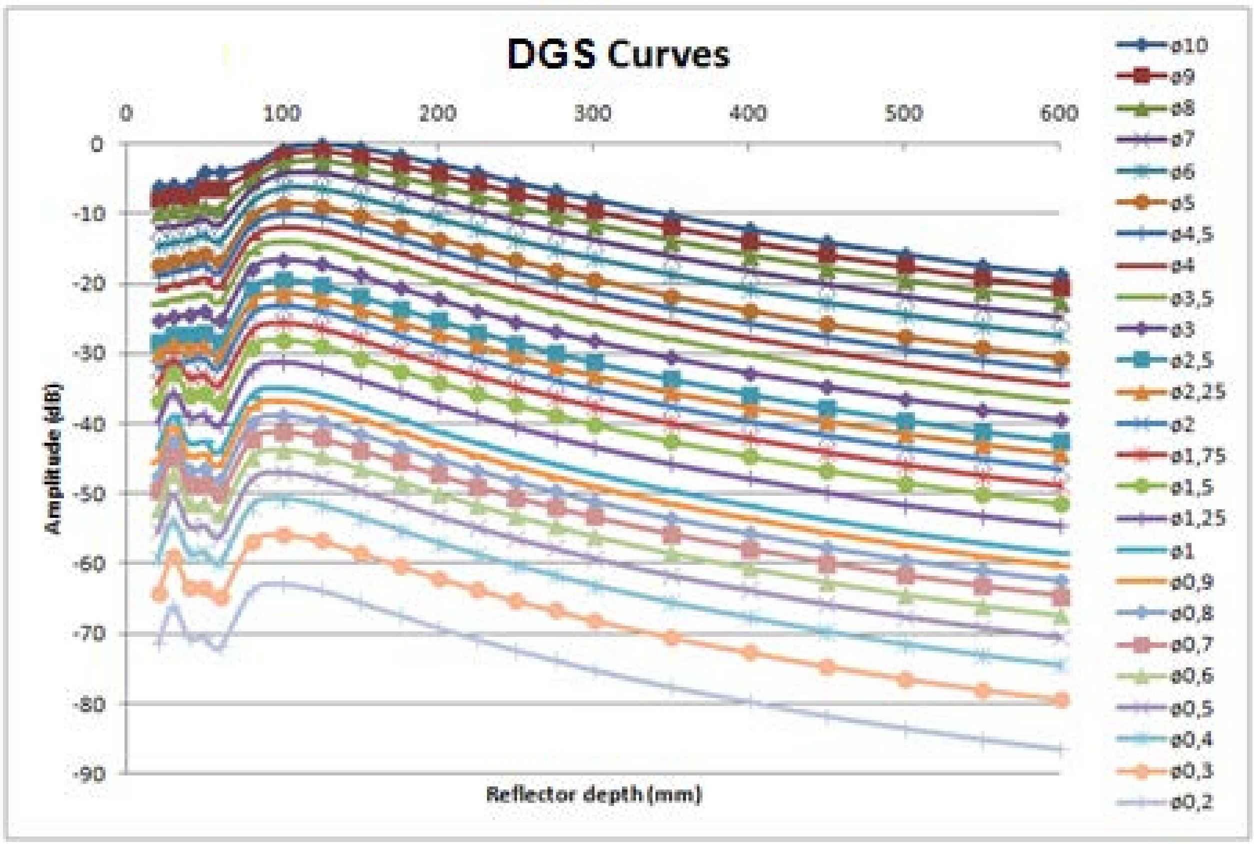
- Simulate a full PoD campaign for ALSTOM implies:
  - To express the UT results in ERS “unit”: It means
    1. Compute the DGS curves
    2. Convert dB in ERS for a lot of points
       (CIVA results are in dB versus calibration holes)
  - To establish the PoD value following the Alstom procedure:
    3. Apply the relevant detection criteria, compute the PoD for 1 transducer
    4. Repeat the process for other transducers and synthetizes the global PoD (L0, S45, etc.)

- Can be done manually … but very long if not automated (PoD = thousands of computations)

EXTENDE has developed a tool for CIVA users in ALSTOM to monitor the whole process

Automation of POD computation

- Step 1: Compute DGS curves *(required to determine results in ERS)*
  - Response of FBHs versus depth, different diameters



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Automation of POD computation

- Step 1: DGS curves

Existing Possibilities within CIVA	**Additional features provided to CIVA by the dedicated tool developed by EXTENDE**
Ability to simulate FBH responses with different sizes and depths	Dedicated interface launching DGS curves computation
Ability to monitor parametric studies in batch	Plotting of DGS curves
	Automatic and optimized *(time and accuracy)* adaptation of scanning vs. FBH size and depth

DGS curves automatically available in an Excel spread sheet
Easy and fast process (10 times faster than a « manual » process)

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Automation of POD computation

- Step 2: ERS Computation of the target flaw response
  - In this study: Rectangular notches with the following variables:

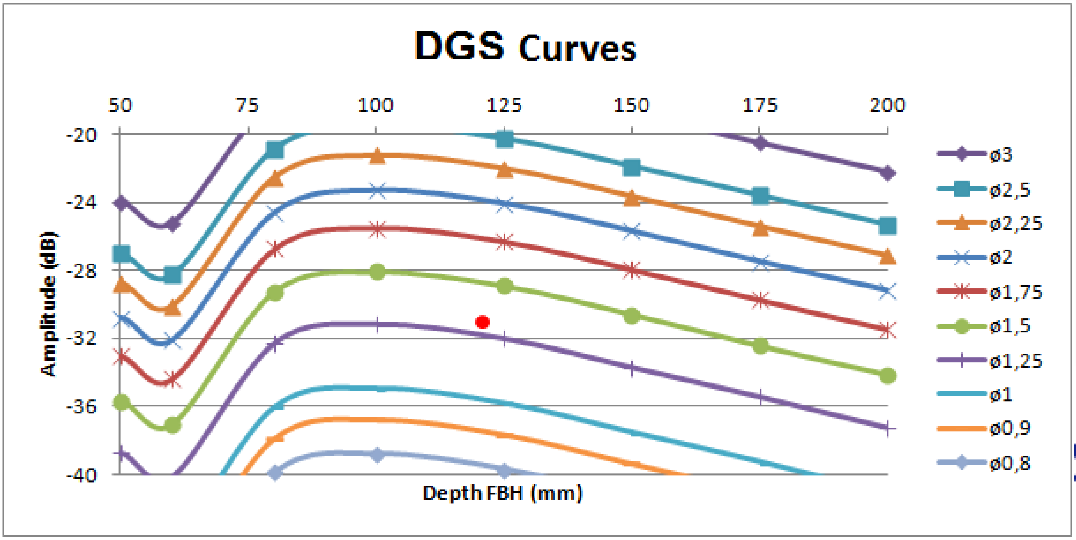
Variable parameters	Variation Range
Flaw Length	Uniform distribution: 1 to 3 mm
Flaw height	Uniform distribution: 1 to 10 mm
Tilt	Uniform distribution: 0 to 90°
Skew	Uniform distribution: 0 to 90°
Disorientation	Uniform distribution: 0 to 180°
Radial position	Uniform distribution: 0 to workpiece radius
Axial Position	Uniform distribution: 0 to 60 mm

  - Very wide flaw properties here (general study).
    Possible to define more precise variation range with adapted statistical distributions (normal, log-normal, etc.)
  - Possible with other variable parameters than flaw properties

Automation of POD computation

- Step 2: ERS Computation of the target flaw

Existing Possibilities within CIVA	Additional features provided to CIVA by the dedicated tool developed by EXTENDE
Able to run series of calculation with random variations of selected input parameters defined by statistical distributions	Automatic ERS computation by interpolation from DGS curves and ERS Value available in an Excel spreadsheet



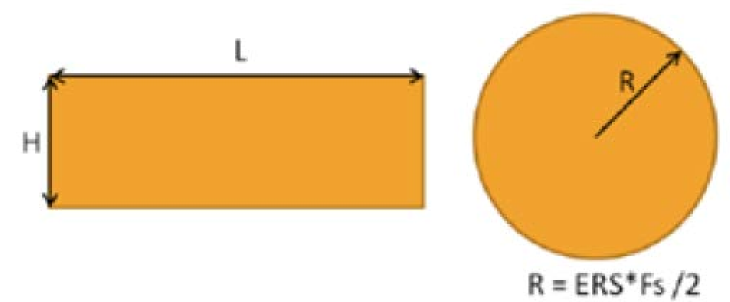
- Flaw depths & signal ampl.(dB) picked up from CIVA
- Quadratic interpolation of DGS curves to get ERS

ALSTOM

Automation of POD computation

- Step 3: Single probe POD computation
  - Versus ALSTOM procedure:
    - Detection criteria :
      Comparison of flaw surface
      with FBH surface
      and security factor “fs”

$$\pi\,(ERS * f_s/2)^2 > L * H$$



    - PoD value :

$$POD = \frac{\text{Number of detected flaws}}{\text{Number of existing flaws in the mock-up}}$$

  - PoD easily obtained once all results translated in ERS and synthetized in a table *(previous step)*

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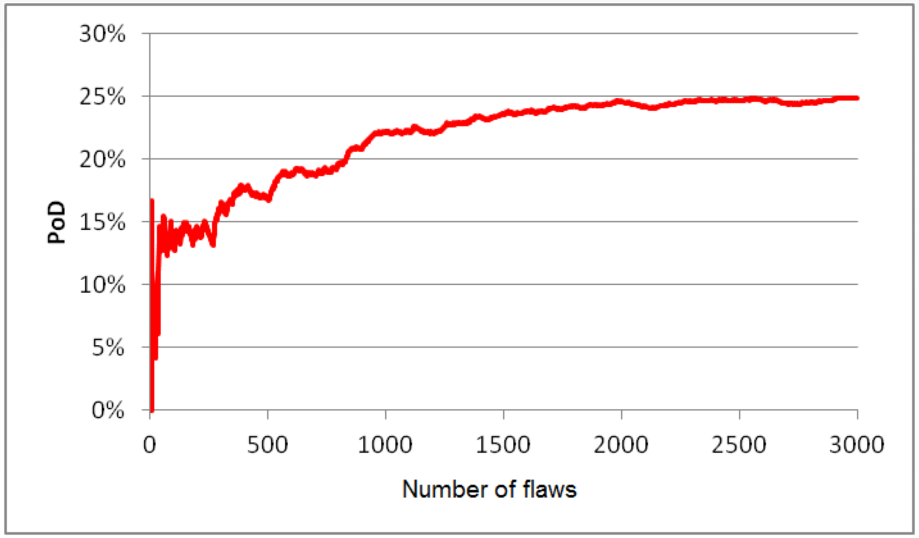
Automation of POD computation

- Step 3: Single probe POD computation
  - Reliable PoD : Need to simulate enough situations
  - → Plotting of "PoD convergence curve" vs number of cases:



  - Here: PoD stabilized around 25% after 2000 simulations
  - NB: If different security factor & more precise type of flaw, PoD would be much higher!

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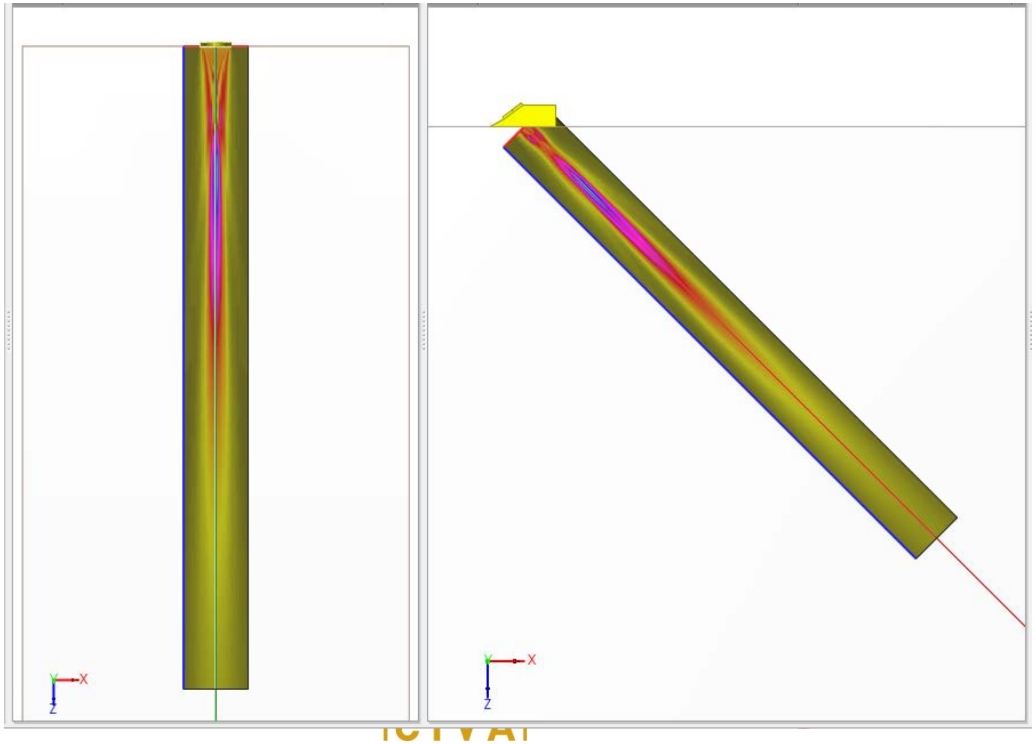
Automation of POD computation

- Step 3: Single probe POD computation

Existing Possibilities within CIVA	Additional features provided to CIVA by the dedicated tool developed by EXTENDE
PoD curves computation following BERENS model (MHDBK 1823-A)	PoD value computation along Alstom criteria
CHENG confidence bound	Dynamic PoD curve to check convergence

Automation of POD computation

- Step 4: Multi probe POD computation
  - Several transducers at different angles involved
  - Example: Long. Waves at 0° and S waves at 45°
    (different inspection plans: Longitudinal, circumferential, etc.)
  - UT beams computed by CIVA:



Automation of POD computation

- Step 4: Multi probe POD computation
  - PoD with several probes is not the sum of PoD for each probe:
    - One flaw is considered as detected if, at least, one probe detects it
    - But PoD does not increase if several probes detect it
    - Whole PoD: Only increases with new probe if detects other flaws than ones detected by previous transd.
  - → Compute the multi-probe PoD assumes to:
    - Run the whole process for each probe (DGS curves, ERS values of the target flaw, Single probe PoD with the same PoD scenario)
    - Tool allow to automatically combine in the relevant way the different "single probe PoDs"

Easy identification of the influence of each probe on PoD

→ Optimization of the inspection and PoD process

Conclusion

- PoD is very costly if done only experimentally: Typical case where simulation can help to increase reliability while decreasing costs
- CIVA allows to simulate efficiently most of NDT inspections and includes a lot of tools to compute PoD
- PoD methodology used at ALSTOM POWER for UT inspections requires additional tool to automate the process
- EXTENDE has provided a tool to Alstom, connected to CIVA simulations
- With this tool, ALSTOM is now able to determine the optimal number of inspections allowing obtaining a convenient PoD

QUESTIONS?