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

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- Modelling PoD in CIVA simulation software
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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:

  \[ \pi (ERS \cdot f_s / 2)^2 > L \cdot H \]

  Comparison of actual flaw surface and ERS value of the signal
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).

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)
- Developed 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

![DGS Curves](image)
Automation of POD computation

Step 1: DGS curves

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

DGS curves automatically available in an Excel spread sheet
Easy and fast process (10 times faster than a « manual » process)
Step 2: ERS Computation of the target flaw response

- In this study: Rectangular notches with the following variables:

<table>
<thead>
<tr>
<th>Variable parameters</th>
<th>Variation Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flaw Length</td>
<td>Uniform distribution: 1 to 3 mm</td>
</tr>
<tr>
<td>Flaw height</td>
<td>Uniform distribution: 1 to 10 mm</td>
</tr>
<tr>
<td>Tilt</td>
<td>Uniform distribution: 0 to 90°</td>
</tr>
<tr>
<td>Skew</td>
<td>Uniform distribution: 0 to 90°</td>
</tr>
<tr>
<td>Disorientation</td>
<td>Uniform distribution: 0 to 180°</td>
</tr>
<tr>
<td>Radial position</td>
<td>Uniform distribution: 0 to workpiece radius</td>
</tr>
<tr>
<td>Axial Position</td>
<td>Uniform distribution: 0 to 60 mm</td>
</tr>
</tbody>
</table>

- 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

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<td>Able to run series of calculation with random variations of selected input parameters defined by statistical distributions</td>
<td>Automatic ERS computation by interpolation from DGS curves and ERS Value available in an Excel spreadsheet</td>
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</tbody>
</table>

- Flaw depths & signal ampl. (dB) picked up from CIVA
- Quadratic interpolation of DGS curves to get ERS
Step 3: Single probe POD computation

- Versus ALSTOM procedure:
  - Detection criteria:
    Comparison of flaw surface with FBH surface and security factor “fs”
  - PoD value:
    PoD easily obtained once all results translated in ERS and synthetized in a table (previous step)
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!
Automation of POD computation

Step 3: Single probe POD computation

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<td>PoD curves computation following BERENS model (MHDBK 1823-A)</td>
<td>PoD value computation along Alstom criteria</td>
</tr>
<tr>
<td>CHENG confidence bound</td>
<td>Dynamic PoD curve to check convergence</td>
</tr>
</tbody>
</table>
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?