FROM RESEARCH TO INDUSTRY

cea tech

VALIDATED INSPECTION TECHNIQUES FOR COMPOSITES IN ENERGY APPLICATIONS : VIT-CEA

INSPECTION TECHNIQUES: ULTRASONIC

list

VITCEA Workshop, 17/02/2015, BAM, Berlin

INSTITUT CARNOT CEA LIST

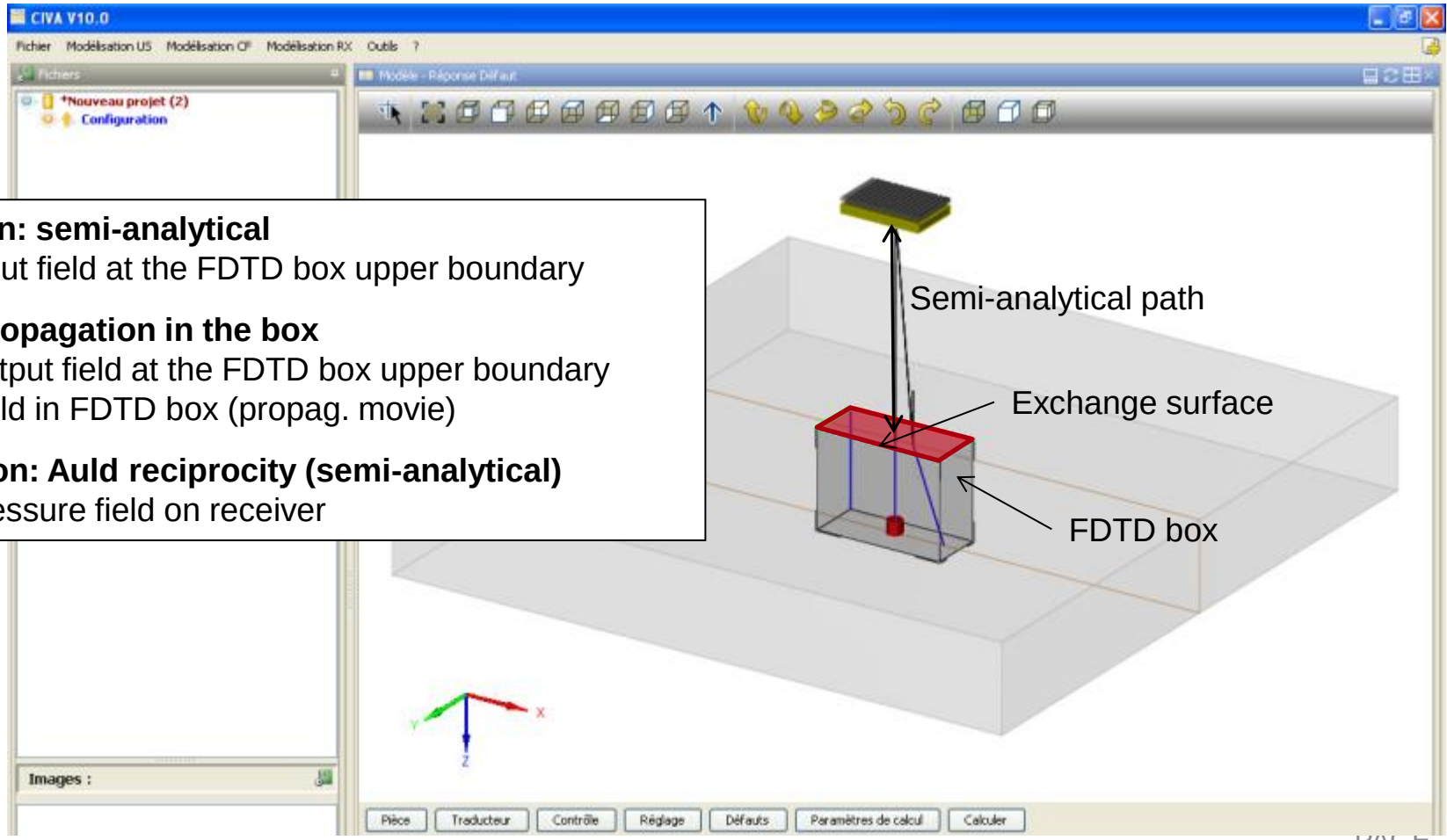
digiteo

Principle of the hybrid method : CIVA/Numeric (FDTD code, N. Dominguez)

AIRBUS GROUP

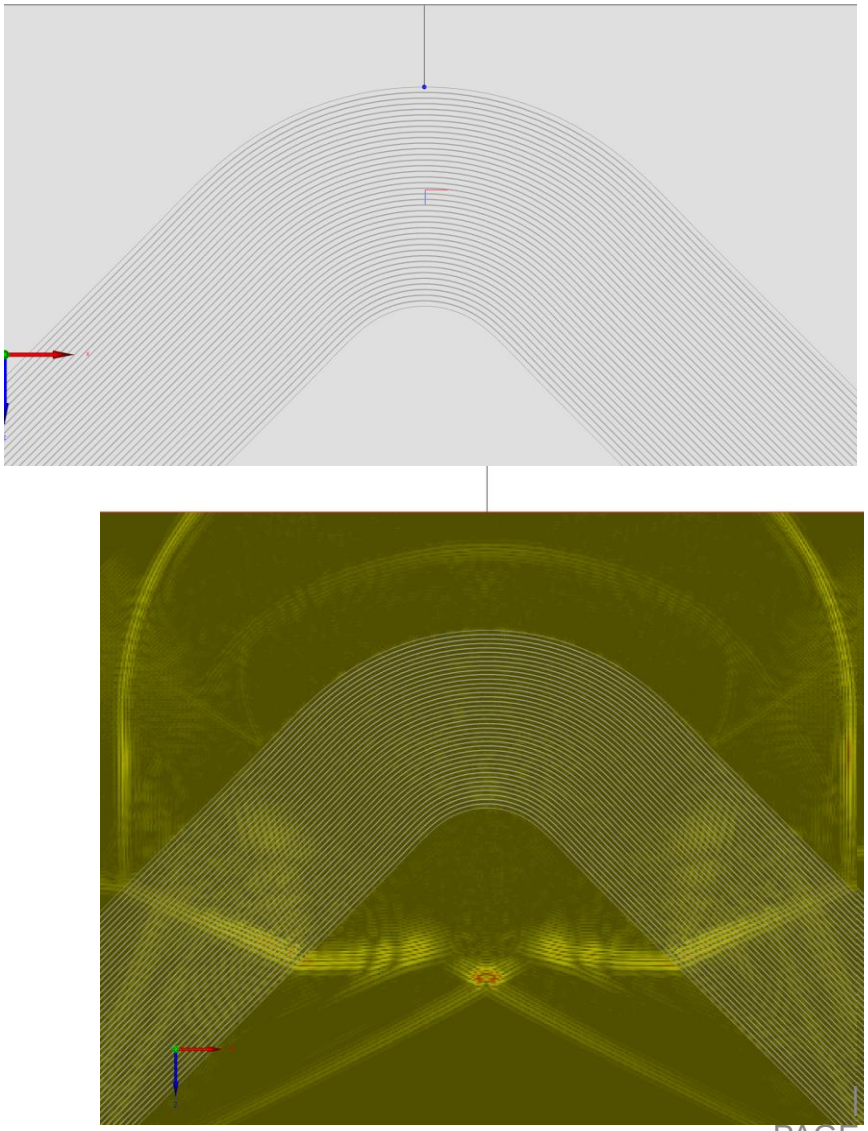
→ Development and integration of a coupling code in CIVA : CIVA/Numeric

1. **Emission: semi-analytical**
   → Input field at the FDTD box upper boundary
2. **FDTD propagation in the box**
   → Output field at the FDTD box upper boundary
   \+ Field in FDTD box (propag. movie)
3. **Reception: Auld reciprocity (semi-analytical)**
   → Pressure field on receiver

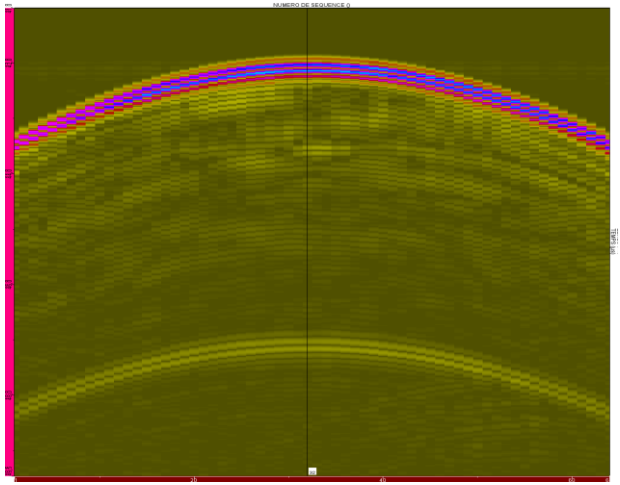


Example of the hybrid CIVA/Numeric code

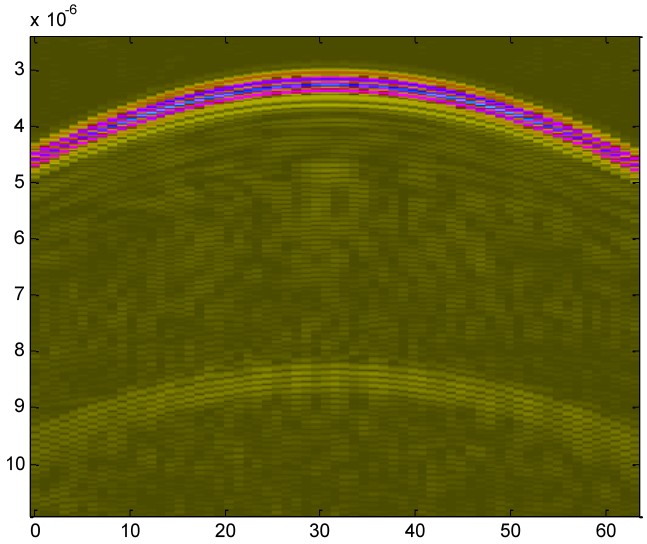
- The part under inspection is a curved composite made of CFRP with an external radius of 14.5 mm and a thickness of 7 mm
- Ply thickness is around 180 µm
- An epoxy layer of 20 µm is inserted between each layer to take the structural noise into account
- The code allows to visualize the propagation of the ultrasonic waves inside the composite taking into account the curvature of the part of the layered structure



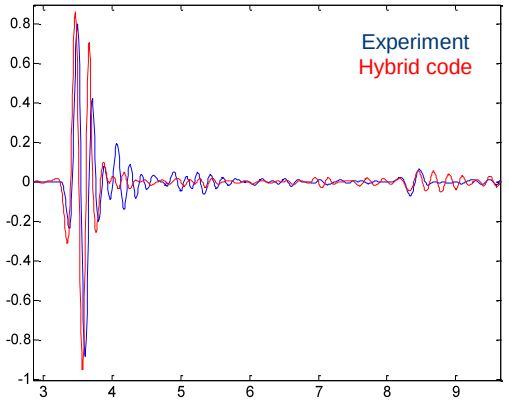
SIMULATION : HYBRID MODELING



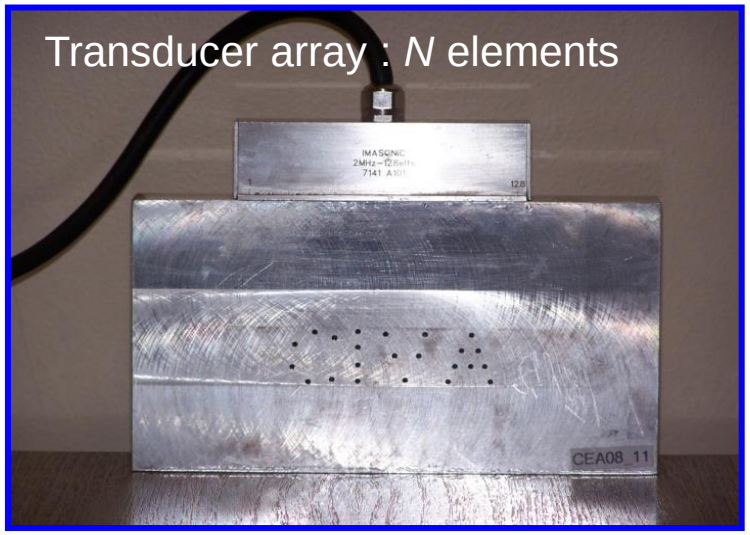
Experiment

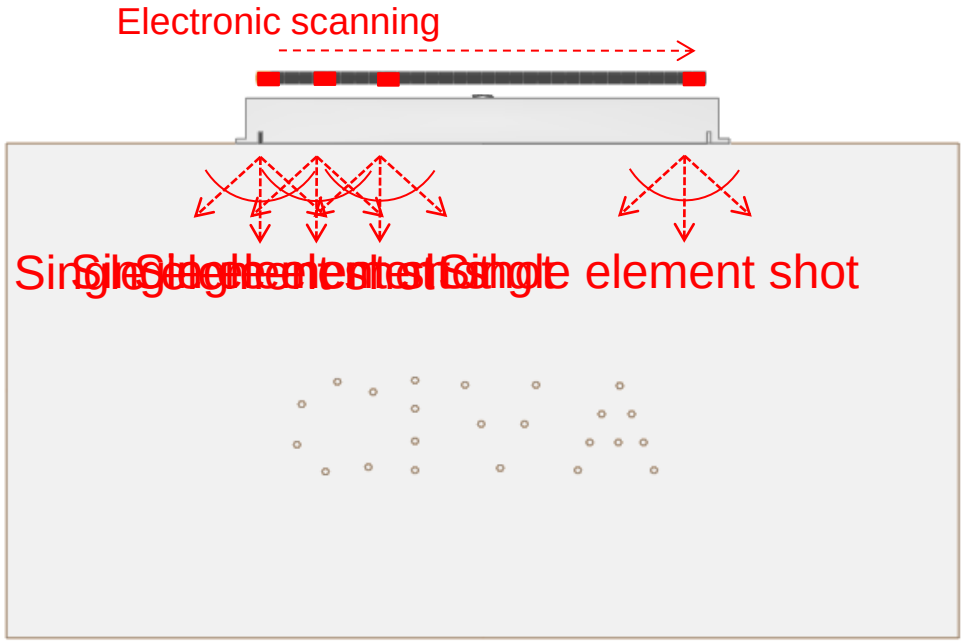


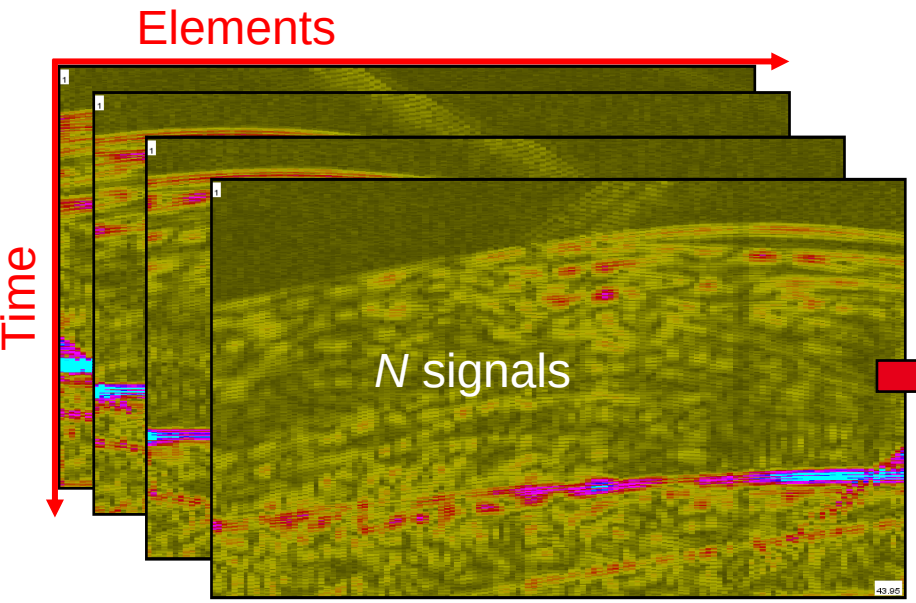
Simulation

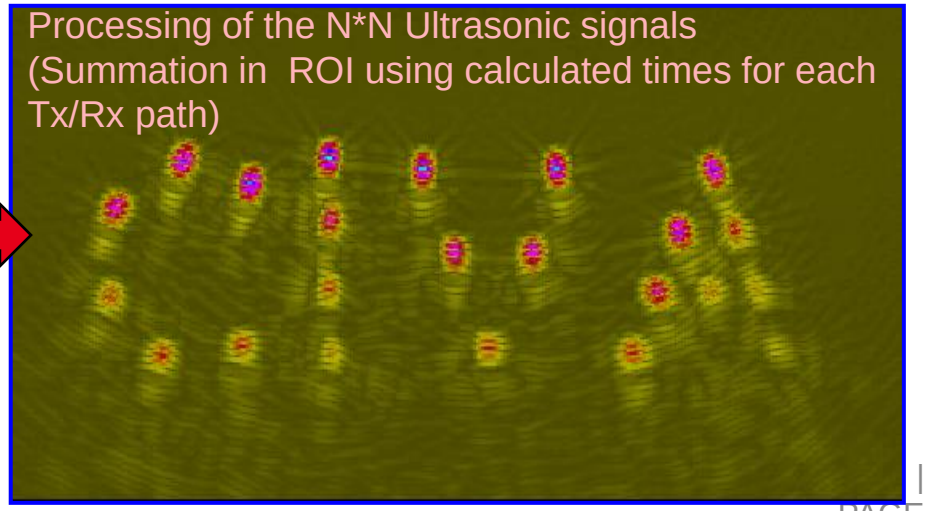


- The model needs to be extended to deal with thick composites
- Attenuation and dispersion need to be taken into account
- Simulation of delamination inspection


Transducer array : N elements
CEA08_11


Electronic scanning
Single element shot


Elements
Time
N signals


Processing of the N*N Ultrasonic signals
(Summation in ROI using calculated times for each
Tx/Rx path)

Use of simulation is a great opportunity to reduce the cost of POD

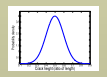
Generation of simulated data with variability

Input parameters → $\overline{X}$ → CIVA N·D·E | 10 → $\overline{Y}$ → Output Values

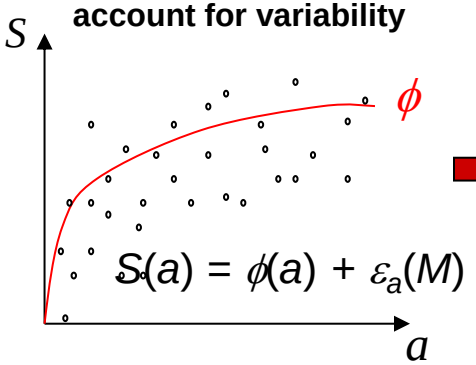
With uncertainty → Uncertainty propagation → With variability

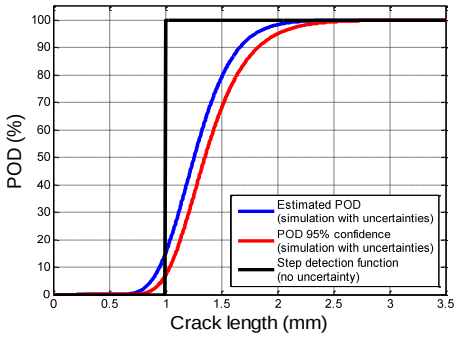
Input parameters:
- Part
  - Dimensions
  - Conductivity
- Inspection
  - Start scan position
  - Scan increment
  - Lift-off
- Flaw
  - Shape
  - Length
  - Height
  - Width



Targeted simulation: account for variability



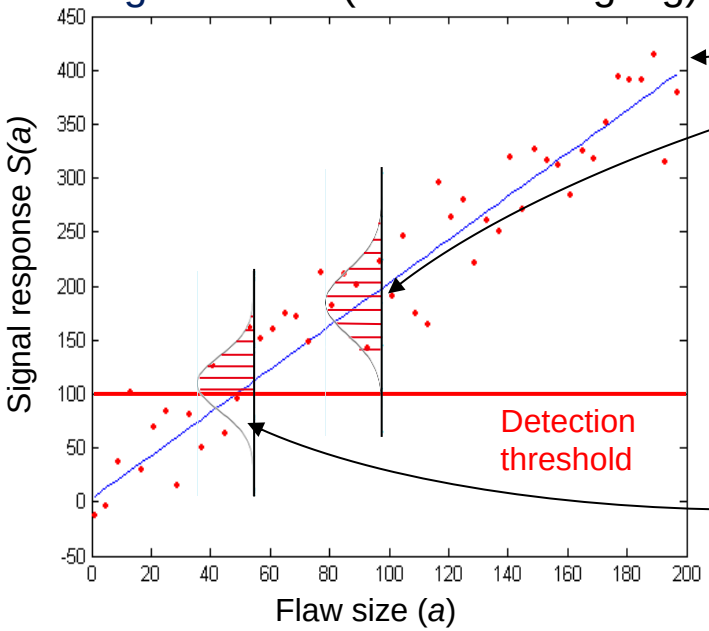


Determination of the POD curve (*):

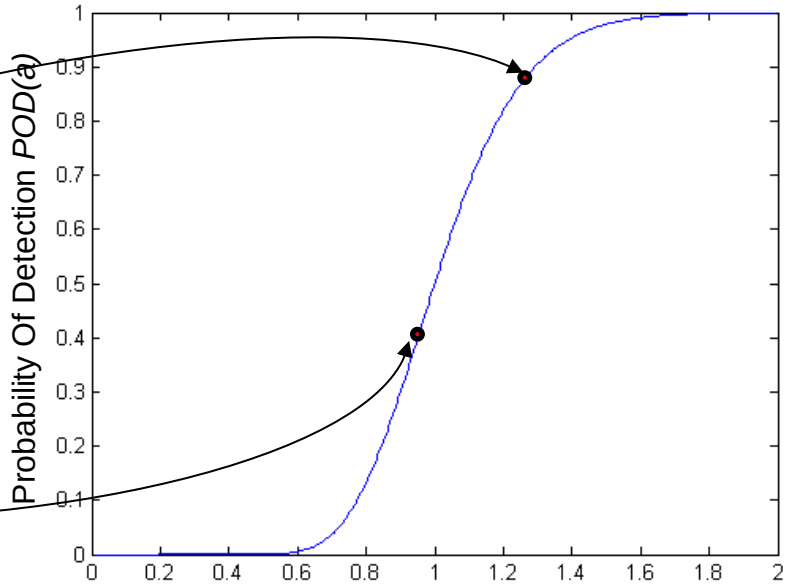
- parametric form : $POD(a) = \Phi\left[\left(\ln a - \mu\right)/\sigma\right]$

Cumulative log-normal distribution function

Regression fit (in lin/lin or log/log)



Evaluated from POD data



Hypotheses to build the POD curve using a parametric form:

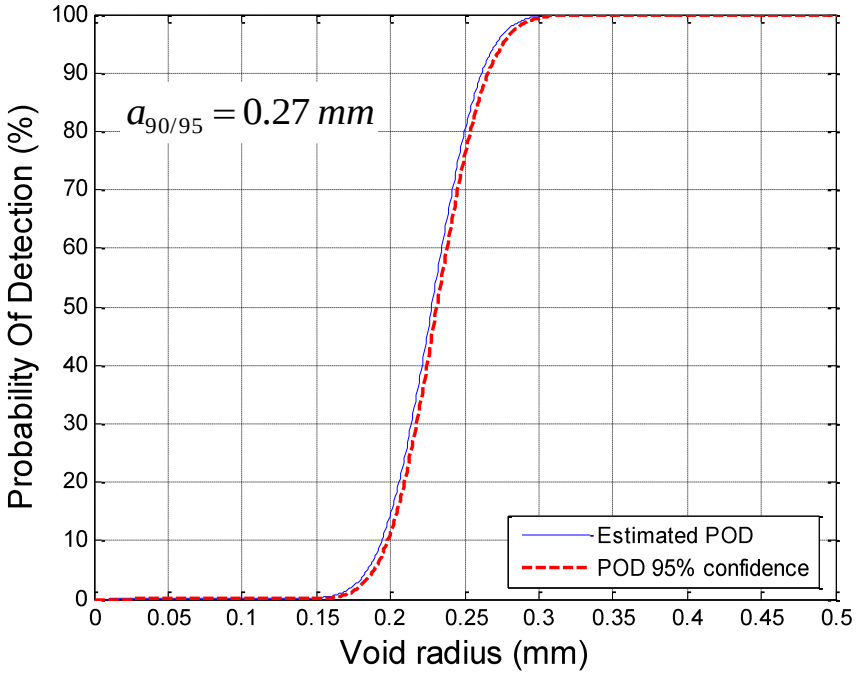
- **linear/linear** or **log/log** relationship between S(*a*) and *a*
- **Gaussian noise**
- **Constance** of the **Gaussian noise** over the flaw size range

→ Tests of these hypotheses are needed

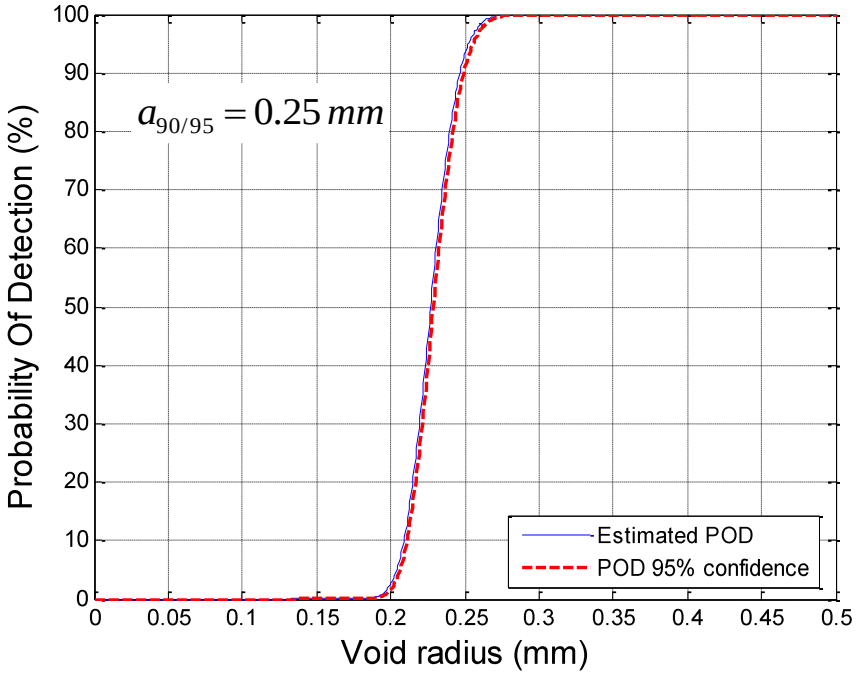
* *A.P. Berens, Metal Handbook, Vol. 17, 9th edition : Non destructive Evaluation and Quality Control*

- POD analysis with thresholds 1

Lin/Lin assumption



Log/Log assumption



Previously used data as « sure value »: ϕ 0.5 mm

This value is confirmed and « consolidated » ($2a_{90/95} \approx 0.5\ mm$)

STATISTICAL ANALYSIS

Activity #14 : Calculation of POD curves for UT phased arrays and air-coupled probes (BAM) experimental or simulated data.

Activity #16 (with PTB and NPL) : Calculation of POD curves from experimental data related to microwave inspection technique.

Activity #18 : Calculation of POD curves for active thermography data (from BAM)

Activity #20 (with NPL) : Calculation and reports describing POD curves from experimental data related to laser-shearography technique.

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