SS15 – NDT Reliability, Ultrasonics, Assisted POD

Probability of detection of an automated ultrasonic testing inspection system in the seamless pipe industry

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France

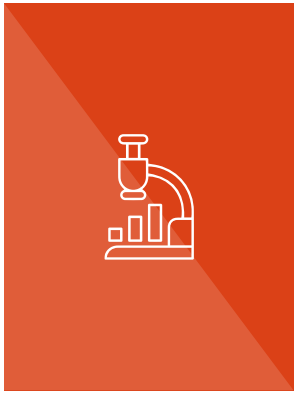
Vallourec is a global leader in high-performance tubular solutions for the energy sector

+12,000
employees

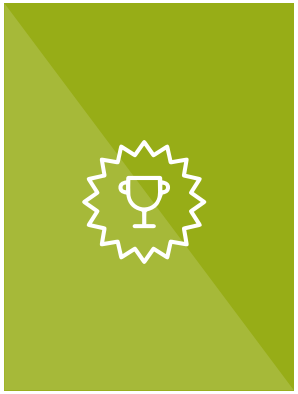
€3.8bn
of consolidated revenue
(€819m EBITDA)

Over 135
years of history and expertise

€36m
spent on R&D



UNDISPUTED CUTTING-EDGE CAPABILITIES
in steelmaking, threading, rolling and heat treatment

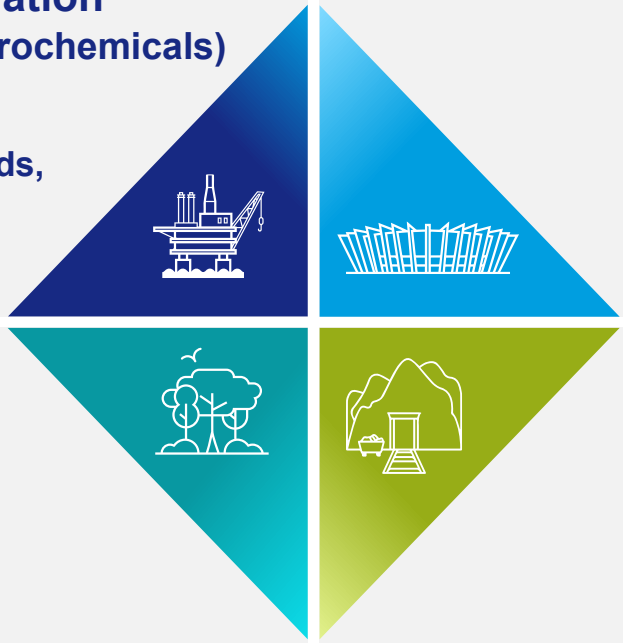


1.244m tonnes
of tubes shipped

We rely on 4 core businesses

HYDROCARBON Exploration & Production (including petrochemicals)

Tubes, connections, and services for **development of oil & gas fields, from the simplest to the most complex**



INDUSTRY

Lightweight and resistant tubes for **automotive, agribusiness, construction, mechanicals, etc.**

NEW ENERGIES

Tubes, connections and systems **for the hydrogen, geothermal and carbon capture markets**

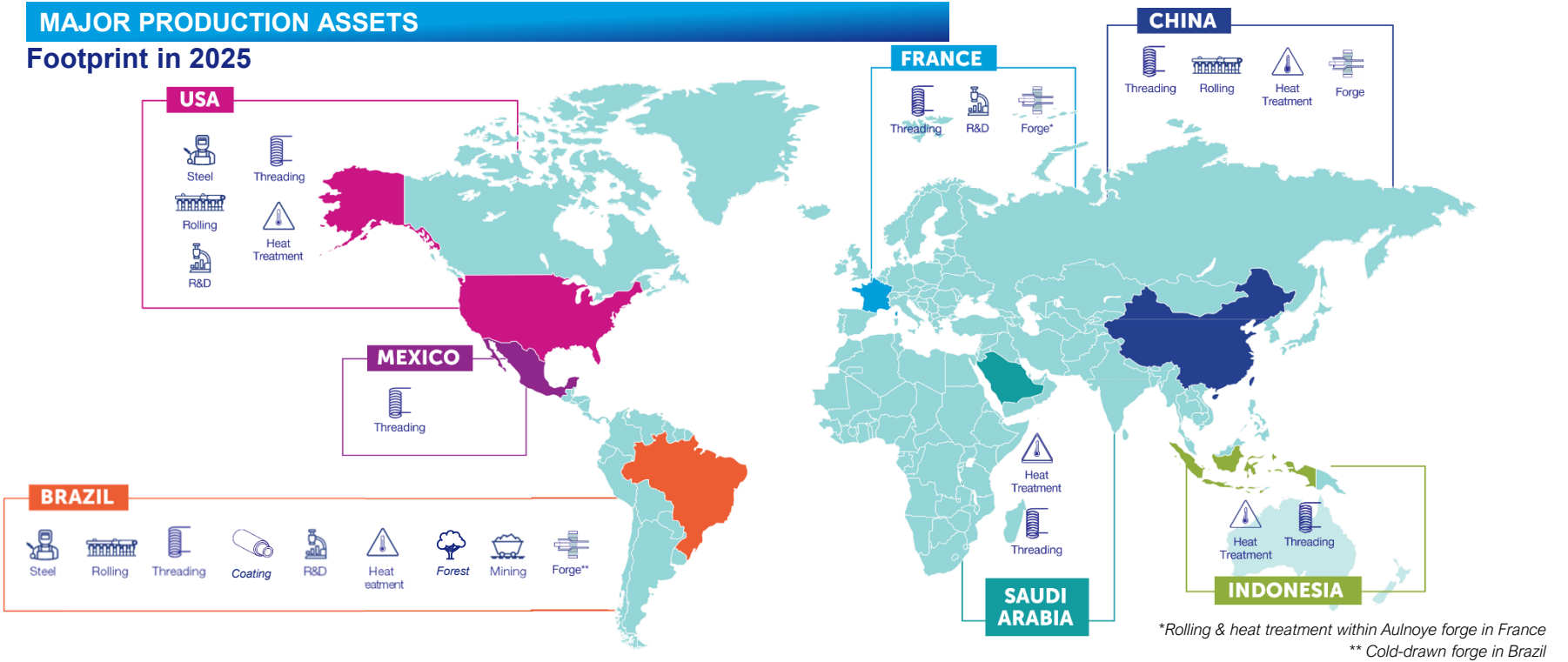
IRON ORE MINE

Operation of an iron ore mine in Brazil for external and internal use

Backed by an international presence

MAJOR PRODUCTION ASSETS

Footprint in 2025



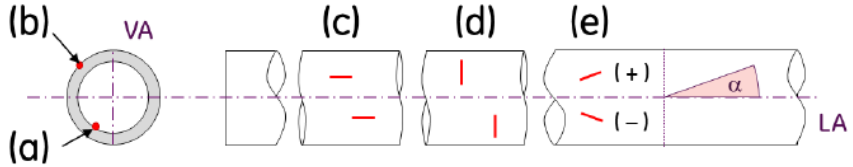
*Rolling & heat treatment within Aulnoye forge in France

** Cold-drawn forge in Brazil

Operating in **20+** **countries**	**c.36** **production sites**	**3** **major R&D centers** (Brazil, France, US)	**150** **VAM® licensees** worldwide

Ultrasonic testing within Vallourec

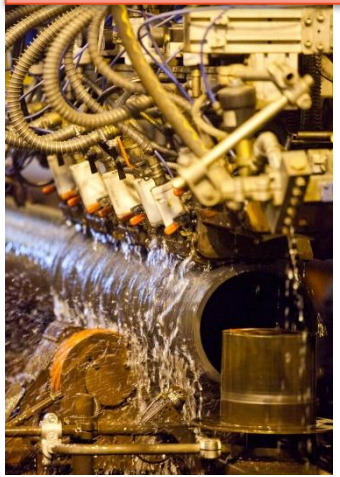
- **Automatic UT benches** are designed to detect **surface breaking defects** on seamless pipes



Definition referring to cross section	Definition referring to longitudinal axis:
(a) Internal flaw (IF)	(c) Longitudinal flaw (LF)
(b) External flaw (EF)	(d) Transverse flaw (TF)
	(e) Oblique flaw (OF)
	+ / – Rotation counter-/clockwise

UT benches use **phased array technology** with fixed angles, electronic beam steering, and linear scans, improving productivity and allowing detection of oblique flaws (paintbrush).

Automatic UT bench located in Brazil (VSB)



What is a PoD curve?

What is a PoD curve in NDT?

A **PoD curve** — Probability of Detection curve — is a **graphical tool** used in **Non-Destructive Testing** (NDT) to quantify how reliably an inspection system can detect flaws.
It answers a fundamental question: **for a given flaw size, what is the probability that my inspection method will detect it?**

What the curve shows?

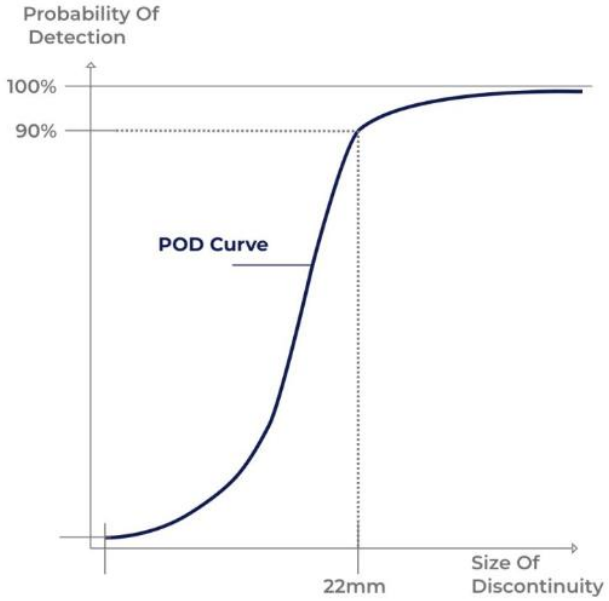
1. **X-axis: Flaw size** - Typically the defect size “a” (depth or length).
2. **Y-axis: Probability of detection** - Values range from 0% to 100%

This is the industry standard—used widely in aerospace.

Why PoD curves matter?

A PoD curve provides a simple, intuitive summary of the detection capability of a NDT system.
It reveals limitations of the bench.
It supports decisions on:

- **optimizing inspection parameters**
- **upgrading equipment**
- **investment (CAPEX) justification >>> replacement**



This says you have probability of 90% to detect a flaw with the size of 22mm.

Source: https://sentin.ai/en/what-is-the-probability-of-detection-pod-in-ndt/

How is a PoD computed within Vallourec?

Step 1

Masterpipe manufacturing

Pipe extracted from production and cut

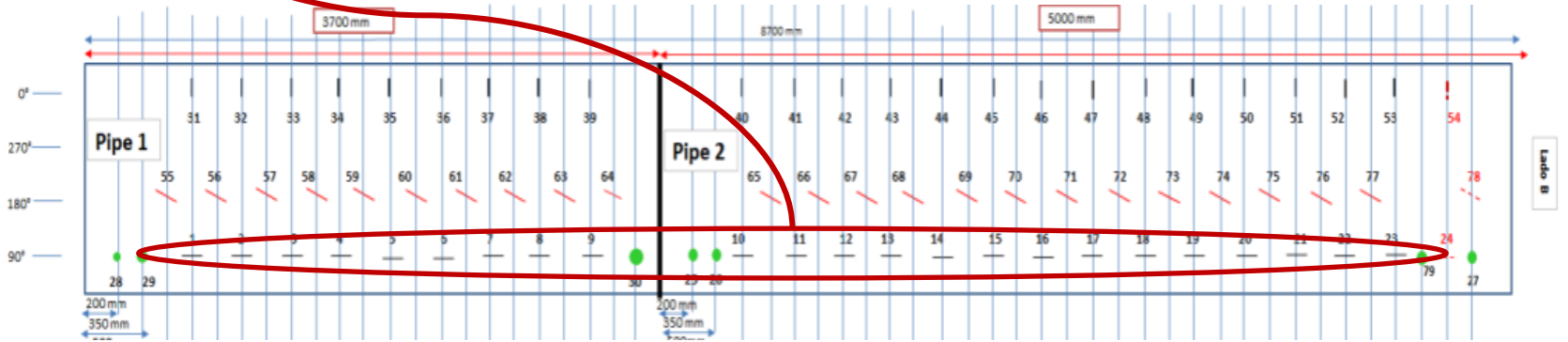
23 LED notches

23 TED notches

23 external oblique notches

Various notch lengths and depths

"LED = Longitudinal External Defects"



How is a PoD computed within Vallourec?

Step 1 — Masterpipe manufacturing

Pipe extracted from production and cut

23 LOD notches

23 TOD notches

23 external oblique notches

Various notch lengths and depths

Step 2 — UT inspections on the bench

25 inspections on the masterpipe (end A to end B)

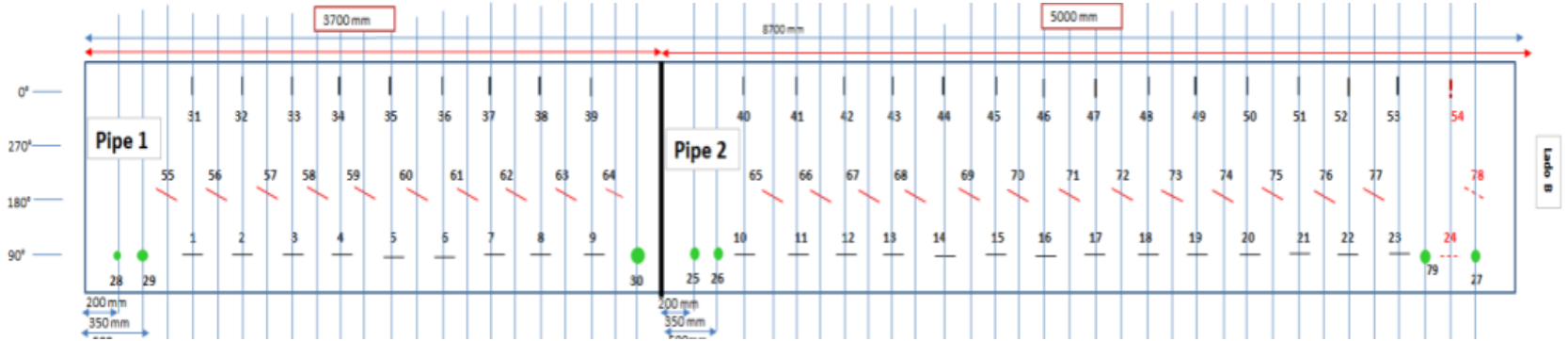
Pipe is flipped

25 other inspections (end B to end A)

Step 3 — Full data analysis

For LOD only = 23x25x4 = **2300 values** to manage

Standard production thresholds are then applied



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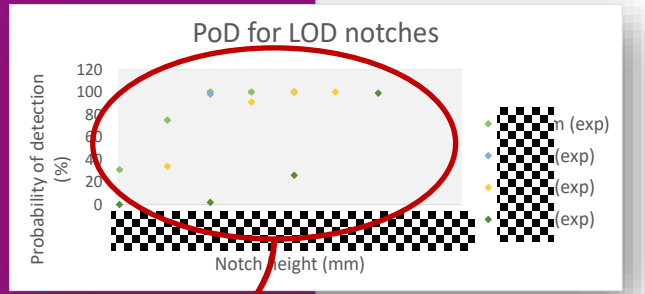
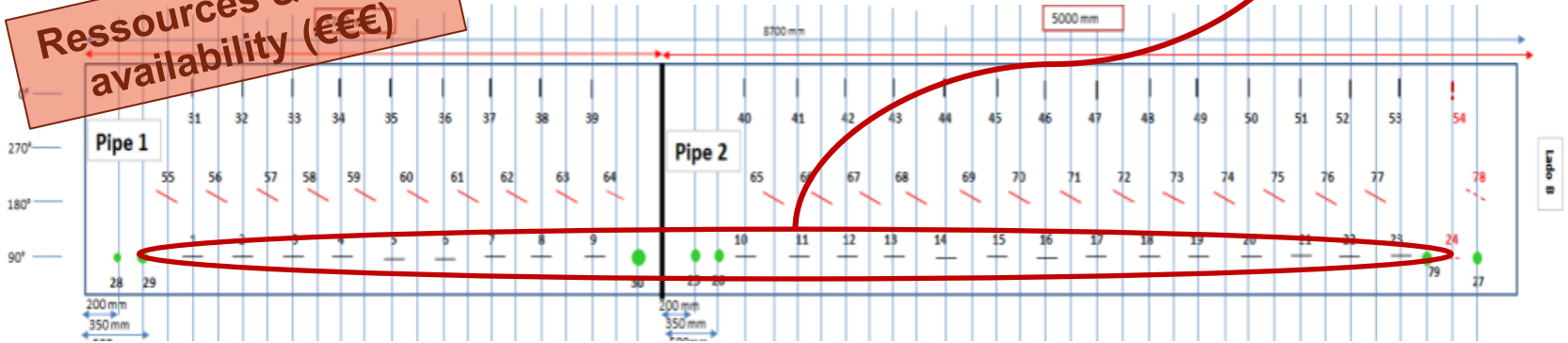
Step 4 — Generation of PoD curves



No simulation

Many experimental trials required

Ressources & bench availability (€€€)



What is a MAPoD curve?

What is a MAPoD?

MAPOD stands **for Model-Assisted Probability of Detection**. It is an evolution of classical PoD analysis that uses physics-based simulation models—rather than relying solely on experimental campaigns—to estimate the probability that an inspection system will detect a flaw.

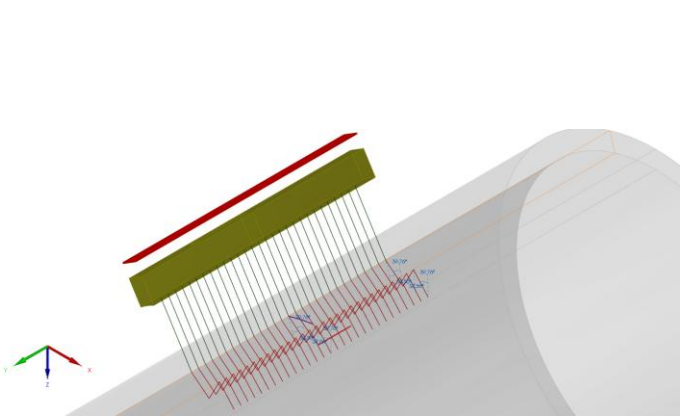
Why MAPoD exists?

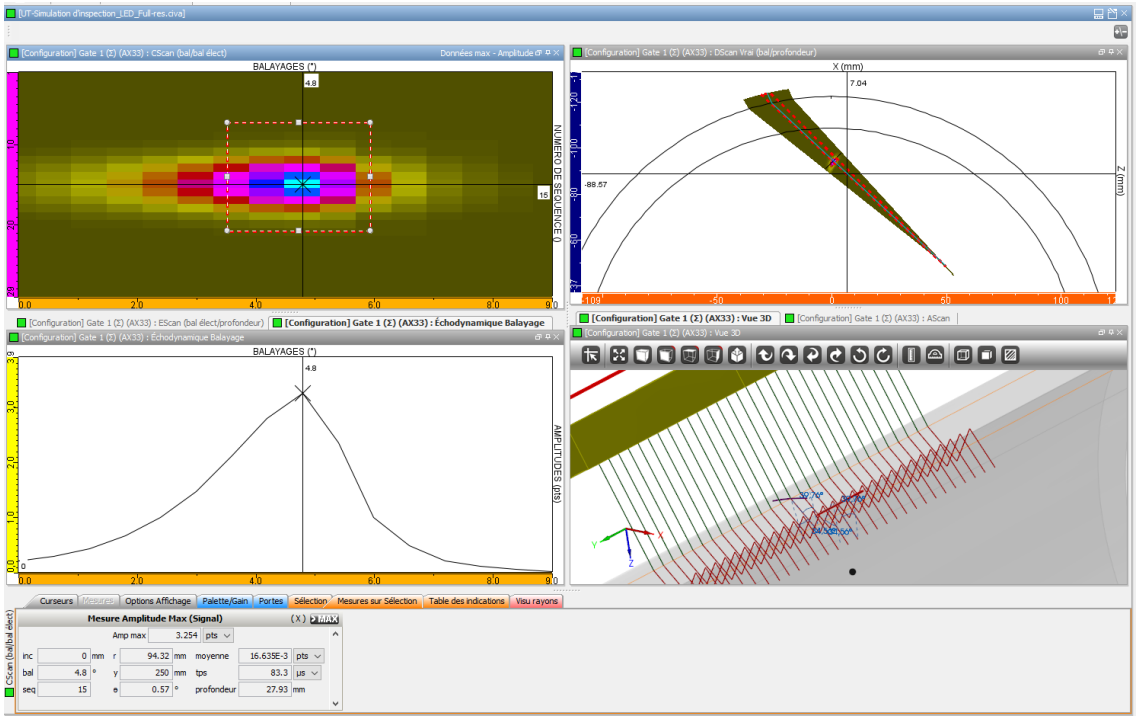
MAPoD provides a practical alternative:

- **Simulation models** approximate or replicate the physical behavior of the inspection process.
- **Statistical methods** use simulation output (sometimes combined with limited experimental data) to calculate PoD curves.

  The approach reduces the experimental burden while **maintaining reliability** of the results.

How is a MAPOD computed within Vallourec?





Full configuration

Linear PA probe with 256 elements, 2MHz

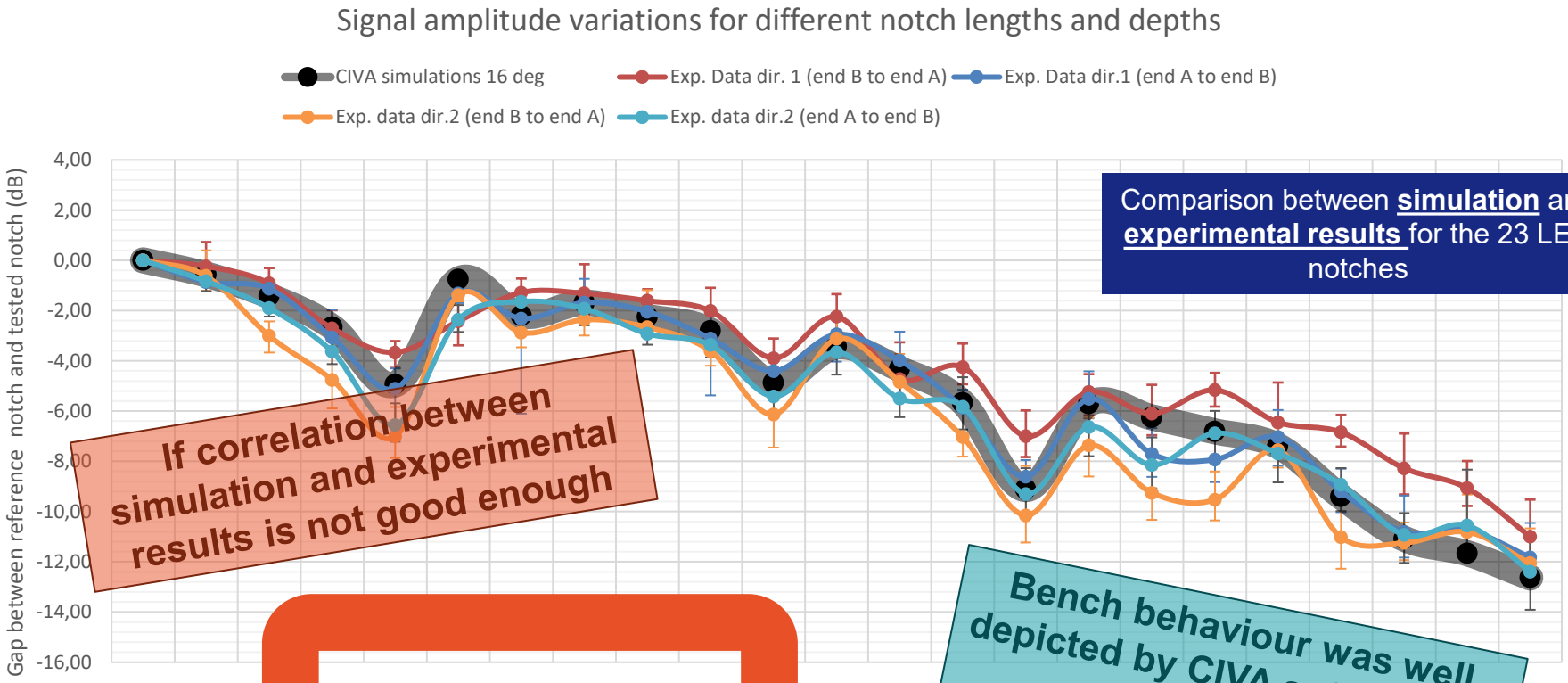
Linear trajectory = 15 increments (15 * 0,6° = 9°)

Step 1 **Gather input data**

Step 2 **First models**

Step 3 **Model simplification**

How is a MAPOD computed within Vallourec?

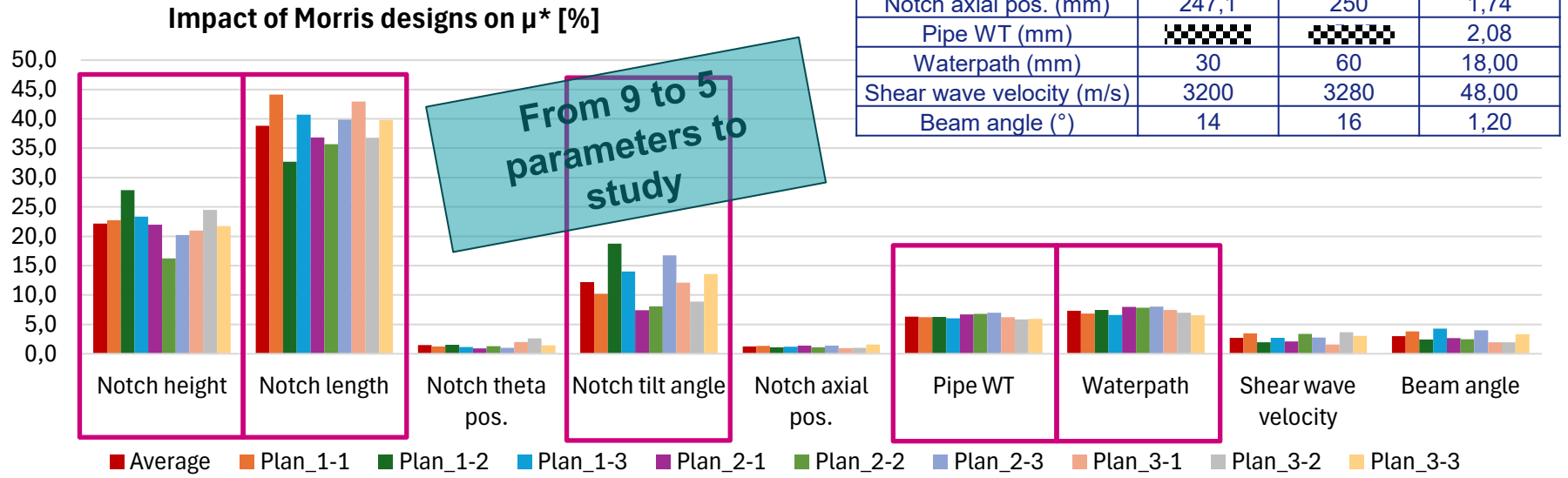


How is a MAPOD computed within Vallourec?

The Morris screening method is a one-at-a-time (OAT) perturbative sampling method for performing global sensitivity analysis (Morris, 1991)

Morris results are evaluated by comparing the mean of the absolute values of the elementary effects (EE) distributors for each parameter (μ*)

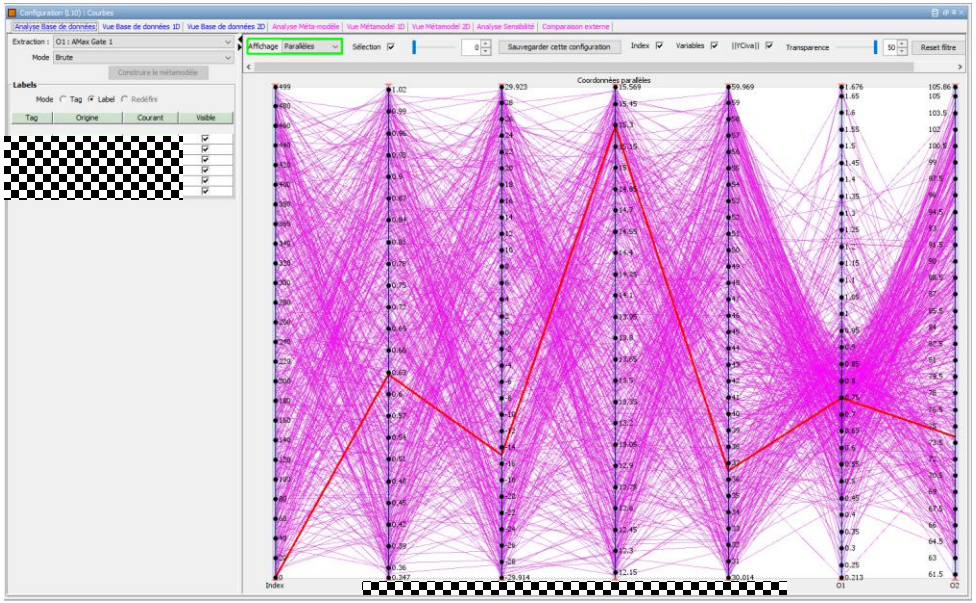
	Mini	Maxi	Variation (3/5)
Notch height (mm)	[redacted]	[redacted]	0,41
Notch length (mm)	[redacted]	[redacted]	12,24
Notch theta pos. (°)	-0,3	0,3	0,36
Notch tilt angle (°)	-30	30	36,00
Notch axial pos. (mm)	247,1	250	1,74
Pipe WT (mm)	[redacted]	[redacted]	2,08
Waterpath (mm)	30	60	18,00
Shear wave velocity (m/s)	3200	3280	48,00
Beam angle (°)	14	16	1,20



Step 1 Gather input data → Step 2 First model → Step 3 Model simplification → Step 4 Model validation → Step 5 Sensitivity analysis

How is a MAPOD computed within Vallourec?

- 6 metamodels were generated with CIVA, one for each of the following notch lengths.
- Varying parameters were the following ones:
  - Notch height = XXXmm to XXXmm
  - Tilt angle = -30° to 30°
  - Pipe WT = XXXmm to XXXmm
  - Waterpath = 30mm to 60mm
- Full random parameter sets
- 500 simulations required to train the metamodel



Step 1 Gather input data | Step 2 First model | Step 3 Model simplification | Step 4 Model validation | Step 5 Sensitivity analysis | Step 6 Generation of metamodels

How is a MAPOD computed within Vallourec?

Step 1 Gather input data

Step 2 First model

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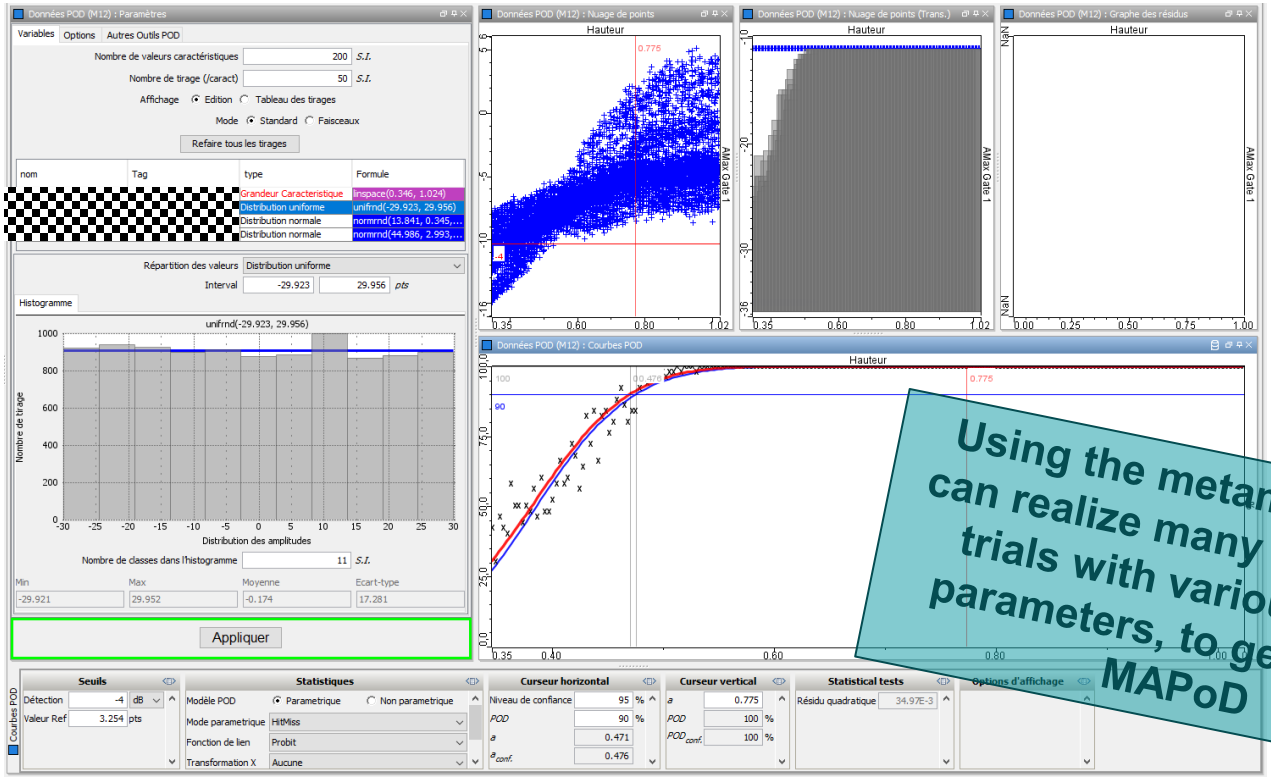
How is a MAPOD computed within Vallourec?



Using the metamodel, you can realize many simulation trials with various input parameters, to generate a MAPoD

Step 1 Gather input data

Step 2 First model

Step 3 Model simplification

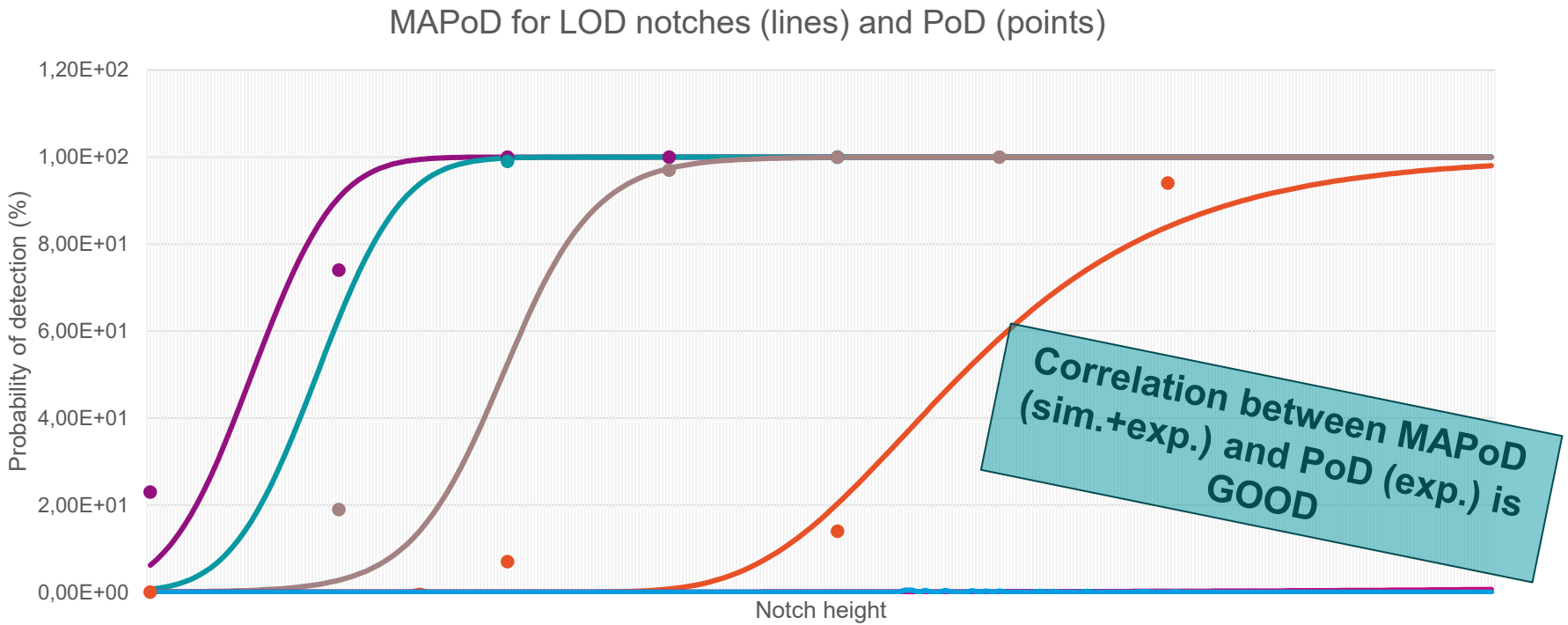
Step 4 Model validation

Step 5 Sensitivity analysis

Step 6 Generation of metamodels

Step 7 Generation of PoD curves

How is a MAPOD computed within Vallourec?



Step 1 Gather input data

Step 2 First model

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Step 5 Sensitivity analysis

Step 6 Generation of metamodels

Step 7 Generation of PoD curves

CONCLUSIONS

First trials using **MAPoD** methodology (real bench, LED/LOD only)

- **Good feedback** on the use of CIVA and on the "**NDT reliability**" training delivered by Extende (please try)
  - Ease of use (available tools)
  - Simulation results VS experimental results >>> good correlation
- **Relevant results** VS experimental PoD

Benefits of MAPoD VS PoD

- **Reduced number** of experimental trials (bench availability, costs)
  - From 23 notches to 3 notches (we still need to validate the CIVA simulation results)
- **Extended possibilities**
  - LID, TID and FBH for example (difficult to manufacture)
  - Other pipe dimensions
- Better understanding of the impact of influencing parameters
- Use of **metamodels**
  - Easy and fast access to infinite number of PoD curves
  - Possibility to define new bench settings and to test them (quality)

Thank you
for your
attention !

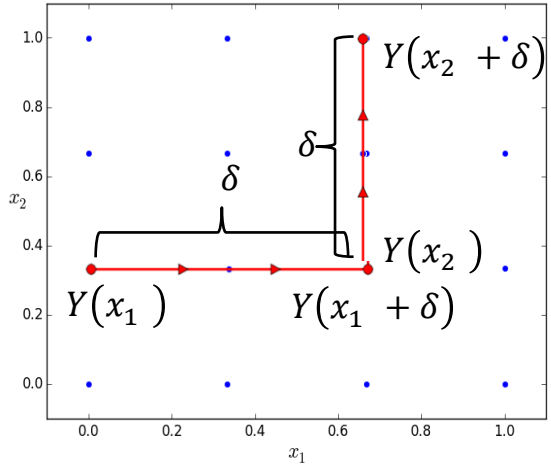
https://youtu.be/W4PGmTY3MSg?si=3XL7wj5XRT7Sx0ll

Morris method

▶ Principle of the method:

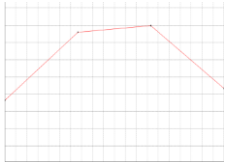
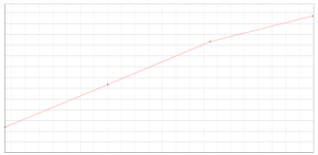
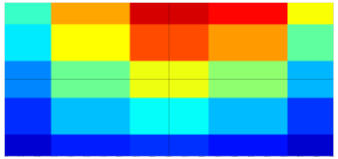
1. Creation of a **one-factor-at-a-time *design of experiments*** :
   - » 1st experiment by assigning a value to each variable
   - » Perturbation δ of each variable **one after another** with a fixed perturbation step
2. Calculation of the effect induced by each perturbation of each parameter on the output data
3. Repetition of the operation starting from another nominal state of the different variables, as many times as the number of selected trajectories, and analysis of the effects induced by each parameter across all trajectories (average impact, etc.)

Example of a trajectory for 2 variables:



Metamodel

- A metamodel in a few words:
  - Starting from a discrete grid of results obtained by varying input parameters (simulations, calculations, or measurements):

  - Application of **interpolation** algorithms to build (from the “known” points) a continuous mathematical model over the variation space of all variable parameters.