Real Defects as the Major Challenge of Useful POD Evaluations

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Abstract

For critical components, the use of nondestructive testing (NDT) systems and their evaluation with probabilistic tools is already a standard procedure for deciding whether the system is capable to detect the critical defects. Often the only available data, which are usable are artificially made reference defects. The reasons for not creating a large amount of real critical defects are economical and also of technical nature: The statistical approaches require a large amount of data and at the same time a wide knowledge about the criticality of the defect and the physical behavior of the NDT system.

There are major advantages to use artificially made reference defects: The manufacturability is guaranteed and, therefore, the defect parameters are known and the costs of the manufacturing process are calculable. The disadvantage is the validity of the defects: Only through a trustworthy use of technical justification and the opinion of experts these artificial defect data can create information for the later use in the reliability studies. This fact is often forgotten in the probabilistic evaluation of NDT systems.

With the use of real and realistic defects the complete design of experiments and their evaluation of the process to get a probabilistic evaluation becomes more difficult. Not only the measurement of the defect size through the master NDT methods or metallographic methods increase the complexity of the evaluation, but also the relationship between the defect and the signal parameters get more sophisticated.

This work will show that the introduction of real defects into the probability of detection (POD) evaluation can be a challenge, which must and can be overcome. The focus of this overview will be on how to plan and conduct experiments for the evaluation of NDT systems. This will be shown on an example of radiographic, ultrasonic and eddy current testing.

APPLIED VALIDATION

How should we handle real defects in the evaluation of NDT systems

Real defects as the major challenge for the meaningful POD evaluation

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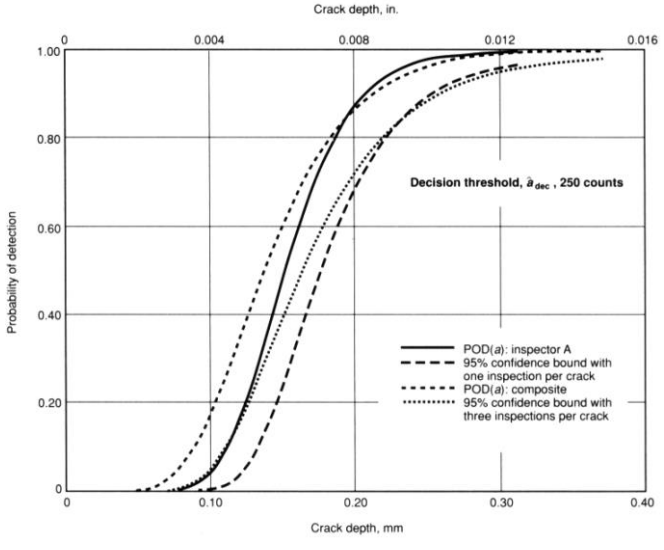
Dr. Ing. Mato PAVLOVIC (Bundesanstalt für Materialforschung und –Prüfung)

Is there only one POD?



A. Berens 1989: NDE Reliability Data Analysis Metal Handbook Vol 17. 9th Ed.

Environmental condition

In the field

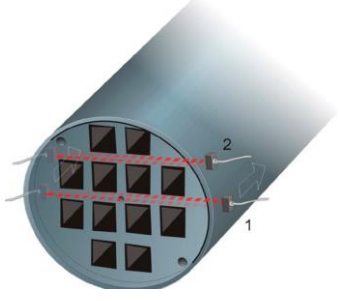
https://www.hersfelder-zeitung.de/lokales/hauneck-haunetal/5000-stahlrohre-werden-verlegt-3050842.html

Laboratory

Gedenkstätte W. C. Röntgen Würzburg

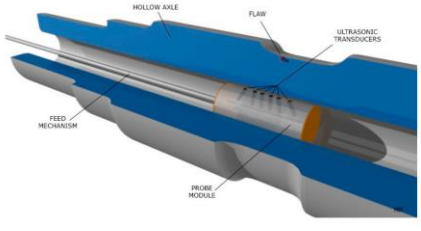
Different testing tasks

Complex testing conditions



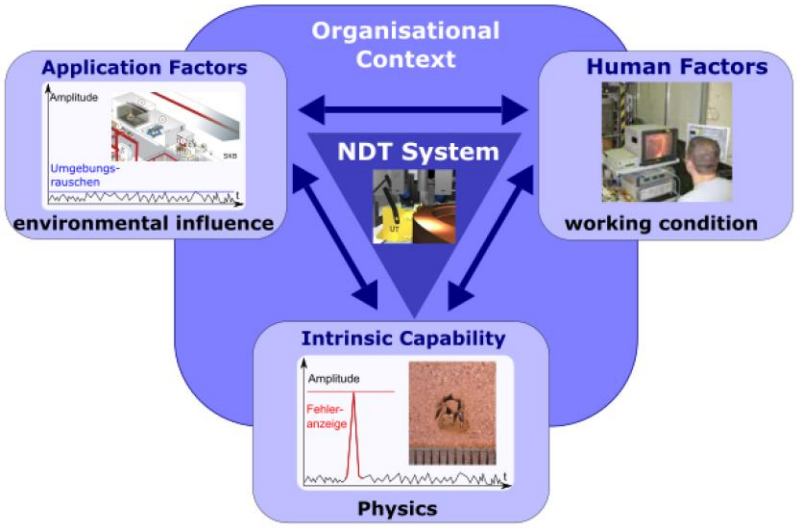
Mato Pavlovic et al 2008 NDT Reliability – Final Report Reliability in non-destructive testing (NDT) of the canister components

Complex contours



Pavlovic at al 2017 Inverstigation to introduce the probability of detection method for ultraonsic inspection of hollow axles at Deutsche Bahn

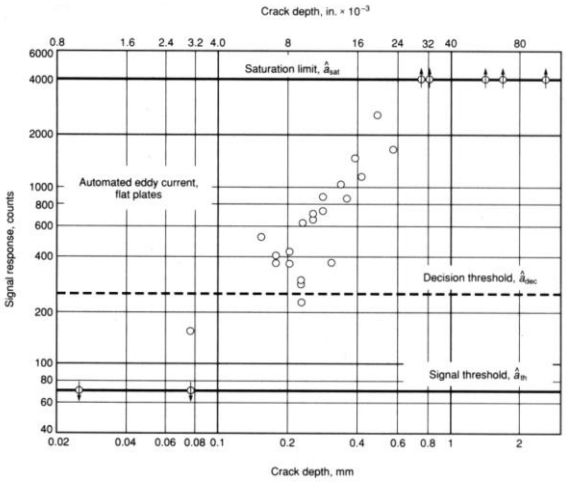
Modular Model



Intrinsic capability: â vs. a

â vs. a: Basis of POD

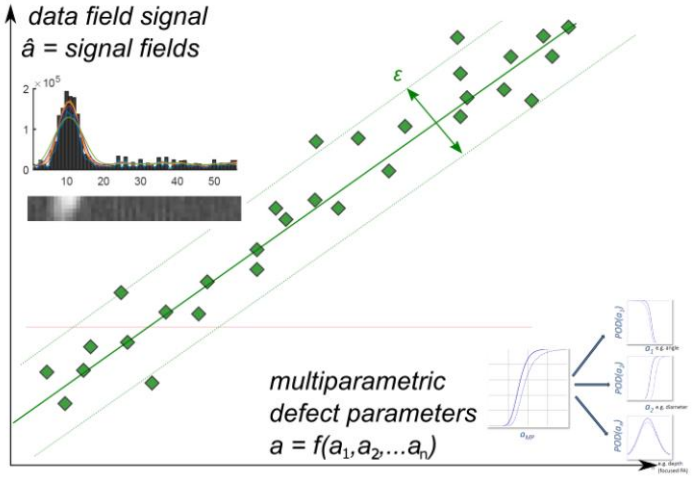
Original relationship between defect parameter and signal response



A. Berens 1989: NDE Reliability Data Analysis Metal Handbook Vol 17. 9th Ed.

â vs. a: Advanced basis of POD

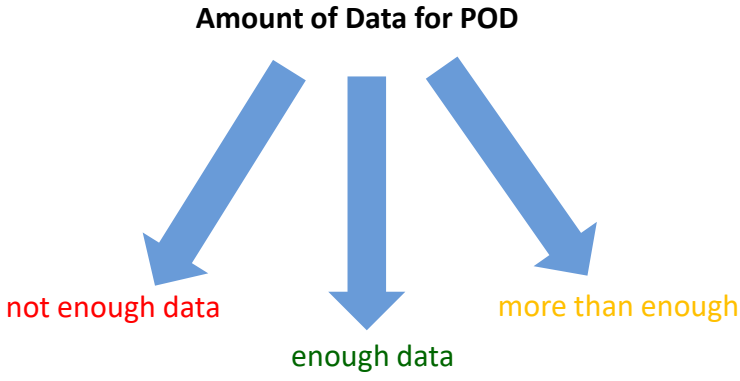
Different approaches to gain a broader model, adequate for more ndt situations



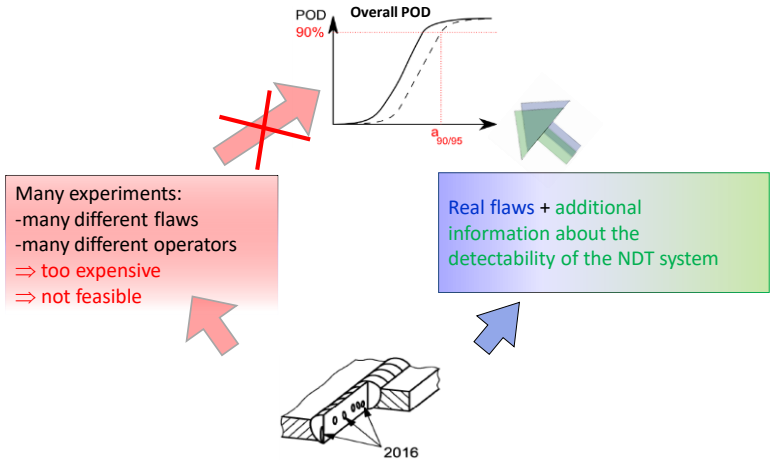
New requirements for new POD models

- General evaluations (multiparametric POD) requires more information
  - Different information pools need to be used for POD (simulation, historic data, technical justification)
  - Experiments are orientation point, verification, high valued data points
- Role of the human influence the intrinsic parameters
  - Capability of detecting forms, areas in noisy surrounding (including spatial data in the POD evaluation: Observer POD, data field POD)
  - Where to test, what and how many, is still mainly in responsible of the operator or the management
- Amount of information and data gets more and more important
  - Continually saving of data
  - Information circle from planning of the component until its recycling

Data situation for the evaluation with POD



Combination of different data: WLSE



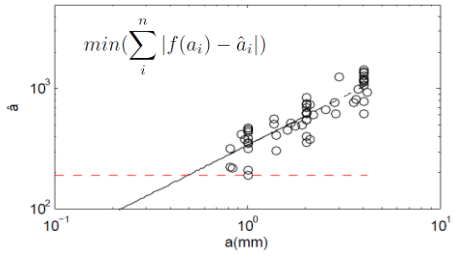
experiments with real flaws

Weighted Least Square Estimation (WLSE)

The assumptions for combining real defects and artificial defects using the WLSE

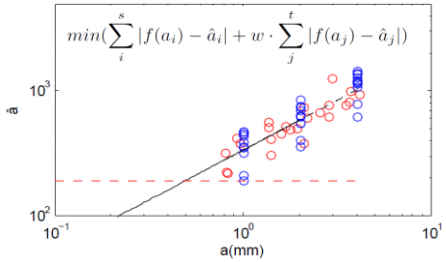
1. Penetrated length of different defect types behaves similar in RT
2. Sizes of the penetrated lengths are known for both defects
3. Weight (w) of the data depends on their significance

LSE



f: estimated function
n: amount of all data

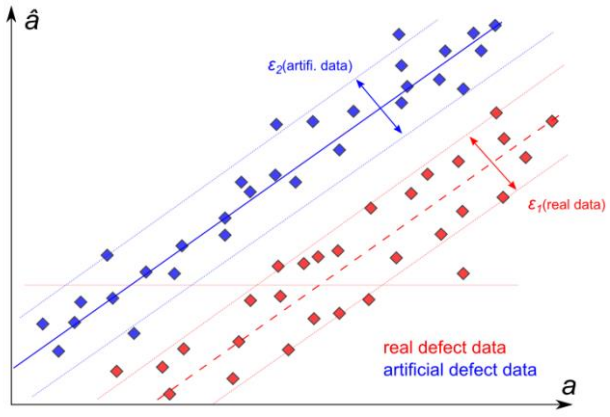
WLSE



f: estimated function
s: amount of real defect data
t: amount of artificial defect data

The use of LSE for different data equals mixing!

Difference between the two data relationships

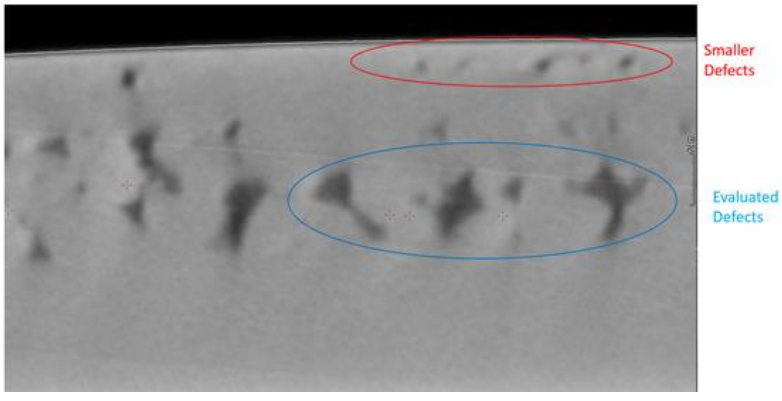


Known reason, due to expected differences in the testing => Transfer function

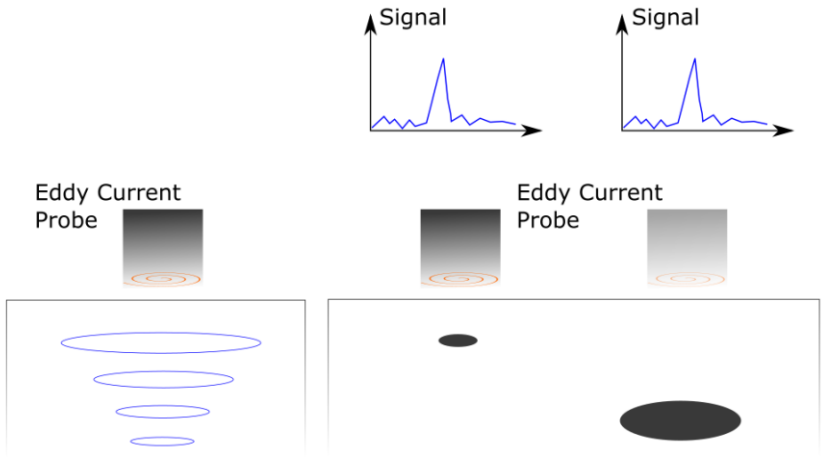
Unknown reasons => further research necessary

Example 1: Challenges with real defects

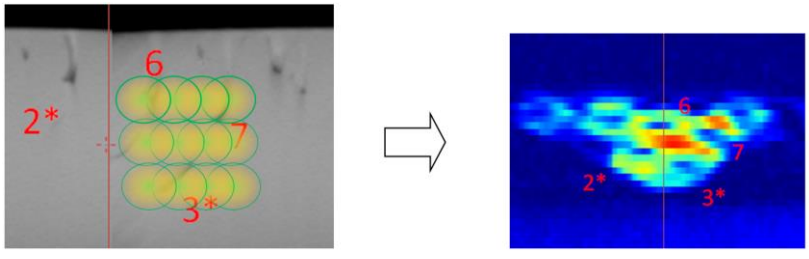
Different response for eddy current testing than expected



Eddy current situation for the small defects



Example 2: Challenges with real defects

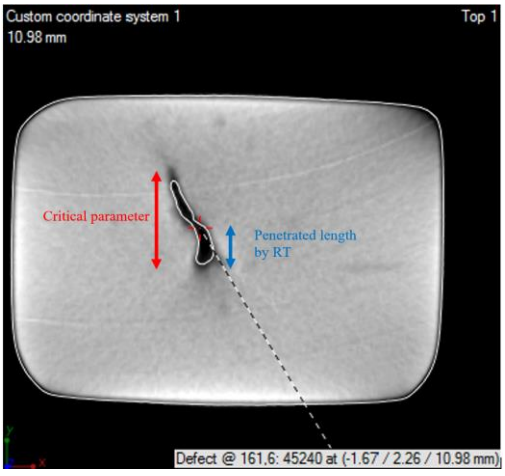


Influences of the different ndt systems:

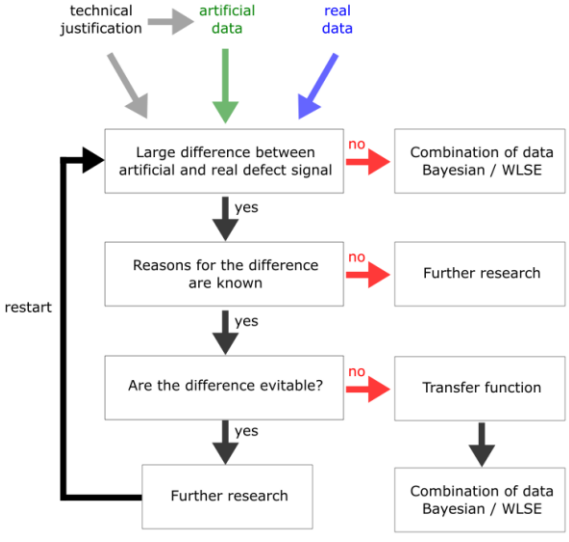
- Ultrasonic testing: Probe size
- Eddy current testing: Coil size
- Radiographic testing: Detector pixel size

Example 3: Challenges with real defects

Difference between corresponding defect parameter and evaluated defect parameter:



Course of action for the evaluation of real defect



Summary and conclusion:

- Real defects are essential for nowadays POD evaluations
  - Objective evaluations are more important
  - POD with former data can be used as additional information
  - POD are a good option as a orientation point for technical justification

- In the evaluation of real defects unexpected ndt behaviour might happen:
  - Different defects or material attributes might influence the ndt system
  - The real capabilities of ndt system is often only shown with real defects (form and spatial information)
  - The expected critical defect parameter is not every time the defect parameter the ndt system is reacting to

  ➔ Real defects are necessary for the POD evaluation

  ➔ POD evaluation for real defects might require complex approaches and the need for new evaluations processes

Thank you for your attention.

Any questions?

For further information:

APPLIED VALIDATION

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