American - European NDE Reliability Workshop

Summary of information presented

at NIST meeting, Sept 21-24, 1999

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American-European NDE Reliability Workshop 2nd meeting

Attendance Motivation:

- Interest in measurement of NDE process reliability to assure book 3 data
- NDE is essential input throughout product life cycle, describing the potential distribution of flaws in a component/structure after inspection
  - Material selection and component design
  - Process control vs. inspect
  - Maintenance (repair/replace) & inspection planning
- NDE needs metrics to define its reliability and sources of variation
  - Analogous to other industrial processes; machining, casting, welding
  - Uniqueness requires conceptual definition for NDE reliability metric
    - Defined in initial 1997 Berlin workshop as R=f(IC) - g(AP) - h(HF)
    - Workshop convened again to define terms in conceptual model, consider methodologies for determining individual functions, and evaluate interdependencies

Presentations from Industry groups

Presentations will be circulated to group

Related POD assessment experiences varied by industry

Aerospace summary

- American DoD aerospace
  - Rigorous approach to defining NDE reliability
  - Operate hardware with known, but monitored cracks
  - Hard requirements to define inspection reliability (Ret.For Cause)
  - Extensive automated systems to collect data (engine programs)
- NASA programs
  - Contractual requirements to show 90/95 capability for fracture crit. items
  - Embedded default capability assumption limits need for physical demonstration (decreasing with advanced weight limited designs)
  - Increasing interest in probabilistic design & NDE at individual contractors
  - Operate hardware with assumed cracks, and known, monitored cracks

Industry perspectives

- American commercial aerospace
  - Structures Design philosophy has focus on visual damage tolerance
    - Don’t fly with known cracks
  - Interest in quantitative knowledge of NDE reliability in directed inspections
    - Concept of “detectable” flaw size used with assumed 63/50 (POD/CL) reliability
    - Assessment effort underway to validate capability at 63/50 & define 90/95
  - Validated NDE reliability helps plan safe and economical maintenance schedule
  - Engines design philosophy is a mixture of fatigue and fracture mechanics
    - Increasingly similar to DoD approach in measuring NDE reliability
    - Rarely operate components/structure with known cracks
      - Exploit initiation life scatter with NDI program to detect initiation of small flaws
    - Dedicated NDE reliability program in place
      - Engine Titanium Consortium
      - Responds to FAA Rotor Integrity Committee
      - Strong effort to model physical processes and integrate with POD function

Industry perspectives

- European commercial aerospace
  - Structures are designed to visual damage tolerance
  - NDE focus is for directed inspections, and life extension
  - Motivated to advance understanding of NDE reliability through fatigue test failure
    - Revealed disparity between capability on lab artifacts, vs. real defects
  - Metrics for NDE reliability defined as 90/95 capability with PFA <= 3%
    - Qualification of a procedure is defined as determining its POD curve and PFA

Other industry groups presenting:

- Transport/Infrastructure (DOT) - Detection of conditions
- Energy production (EPRI) - Human factors focus
- Petrochemical - Use of reliability to justify technology change
- Nuclear - Technical Justification approach to defining reliability

Diversity provided challenge to develop comprehensive definitions

1997 Berlin Definitions
R=f(IC) - g(AP) - h(HF)

Reliability of an NDE system applied is the sum of functions of:

- IC, the Intrinsic Capability (generally considered an upper bound)
- AP, the effect of Application Parameters, such as access restrictions, surface conditions, material and flaw vagaries reduces the capability of the NDE system
- HF, the effect of Human Factors, generally reducing the capability or effectiveness further (but considered by some to be a merge of IC and AP)

Consensus on need to define functions and their arguments more clearly

- Establish function boundaries
  - Role of modeling
- Values to be deterministic, stochastic
- Form of a deliverable?
  - Code/standard
  - Guideline/practice

1999 NDE Reliability Lexicon

Initial inputs/concerns in Boulder:

- Conceptual model should be more mathematically correct
  - eg. Human factors should not be a debit against application parameters
- Need differentiation between theoretical and best practice within IC
  - IC may be considered a measurement of failure of the system design
- Need clear/separate role for modeling activities
- AP needs to be parsed into target and loss components
  - Design activity establishes target to be measured in “lab” environment
    - Expected flaw, environment, NDE technology
  - Loss function arises from vagaries of applied inspection
    - Estimated from models, existing data and limited physical trials
- HF should include only effects of man/system interaction

Consensus Reliability Definitions for NDE

Reliability-

- NDE reliability is the degree that an NDT system is capable of achieving its purpose regarding detection, characterization and false calls

NDE System-

- The procedures, equipment and personnel that are used in performing NDE inspection

Ideal Capability IC (formerly intrinsic)-

- The hypothetical optimal performance of an NDE technique based on the governing physical principles

Application Capability AC-

- The degree to which an applied NDE system achieves its intended purpose, excluding human factors. It is defined in the context of the specification of expected application parameters

Reliability definitions cont.

Application Parameters AP (arguments to AC function)-

- The factors concerning material conditions, discontinuities, procedure and equipment that influence the ability of an NDE system to consistently meet its stated application capability

Human Factors-

- Physical and cognitive elements which impact performance of the NDE system

Revised conceptual relationship:

$R = f\,[AC, HF] \leq IC$

and,

$AC = f\,(AP, HF) \leq IC$, where $HF = 0$

Supplemental Definitions

Detection-

- Threshold-driven identification of the existence of a signal/indication to be of interest or worthy of further investigating

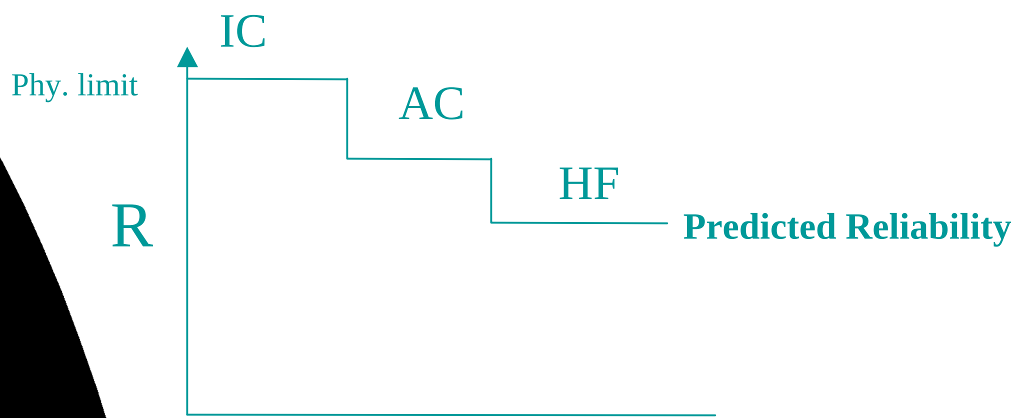
Signal/Data Interpretation-

- Deciding relevance of a signal/indication as being valid for further indication/materials characterization

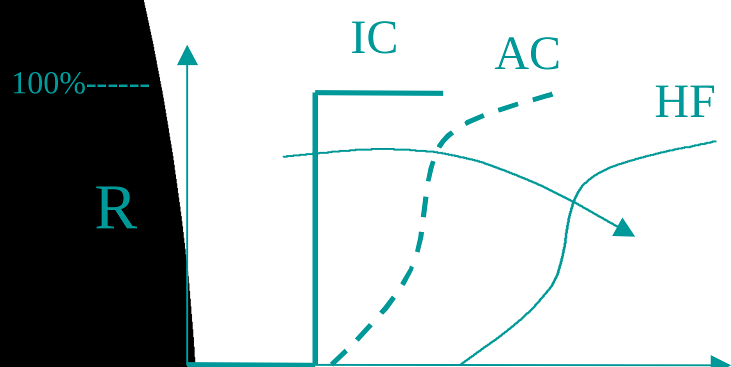
Indication Characterization-

- Estimation of size, location, orientation, type, nearest neighbors

Graphical Representations of NDE Reliability



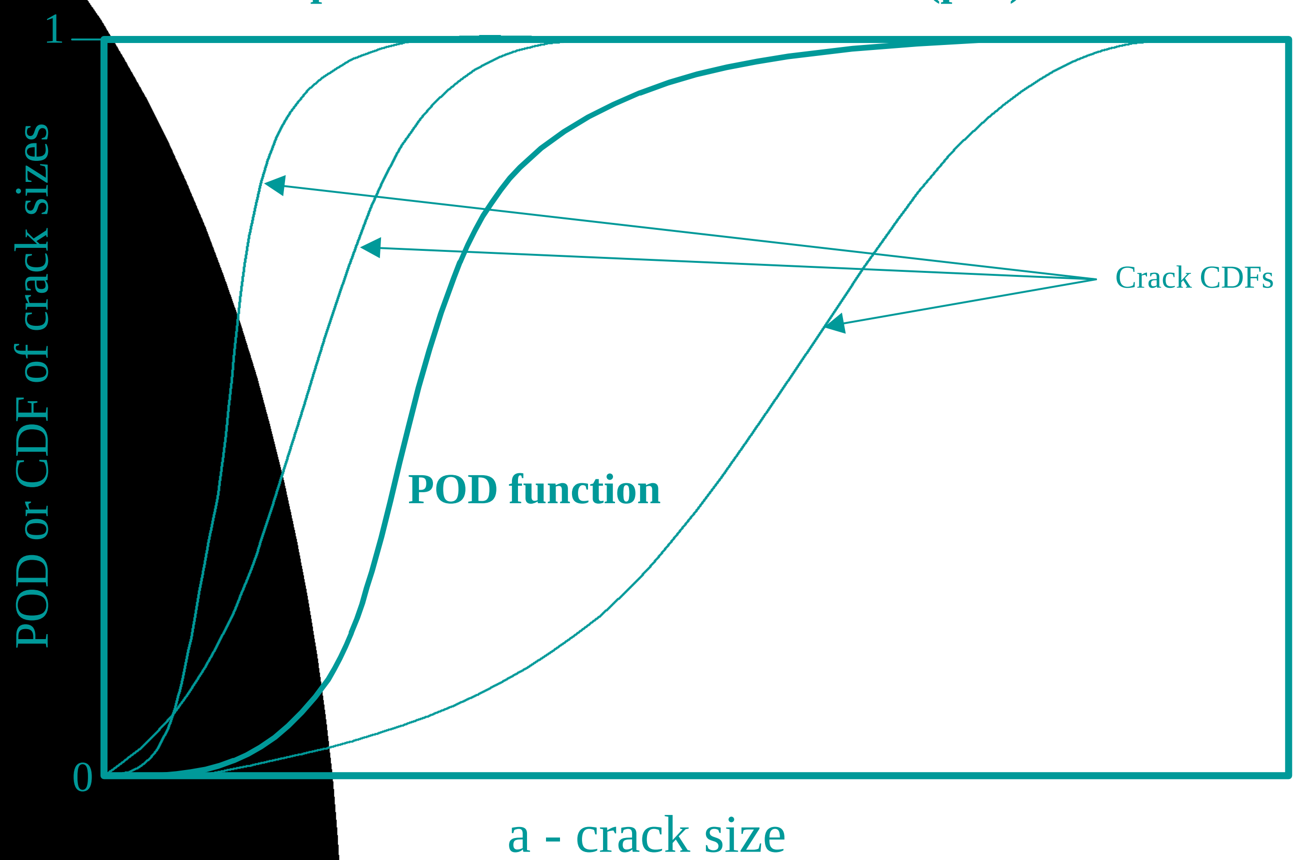
… or in terms of probability



a, or condition measured

Import of NDE Reliability to Design and Life Cycle Management

Example defect size distributions and R(pod) function



Sufficient description of NDE reliability enables comparison to flaw CDF

Observations on Workshop

- Consensus effort on reliability definitions supports published work
- Improved definition/clarification of functional roles
- Economic valuation and safety assurance interests in NDE Reliability expanding throughout industry groups
- Increasing interest in providing more complete reliability information:
  - POD with PFA
  - Distributions in lieu of point estimates
  - More intensive efforts to define Application (Design/NDE interaction)
- Desire for consistent methodologies
  - Facilitates creation of real flaw data library
  - Facilitates process metrics culture
  - Concerns over format (“law”/guide...), proprietary data…
- Recognized need for modeling efforts to reduce cost of information
- Dual emphasis on understanding HF influence and reducing through automation

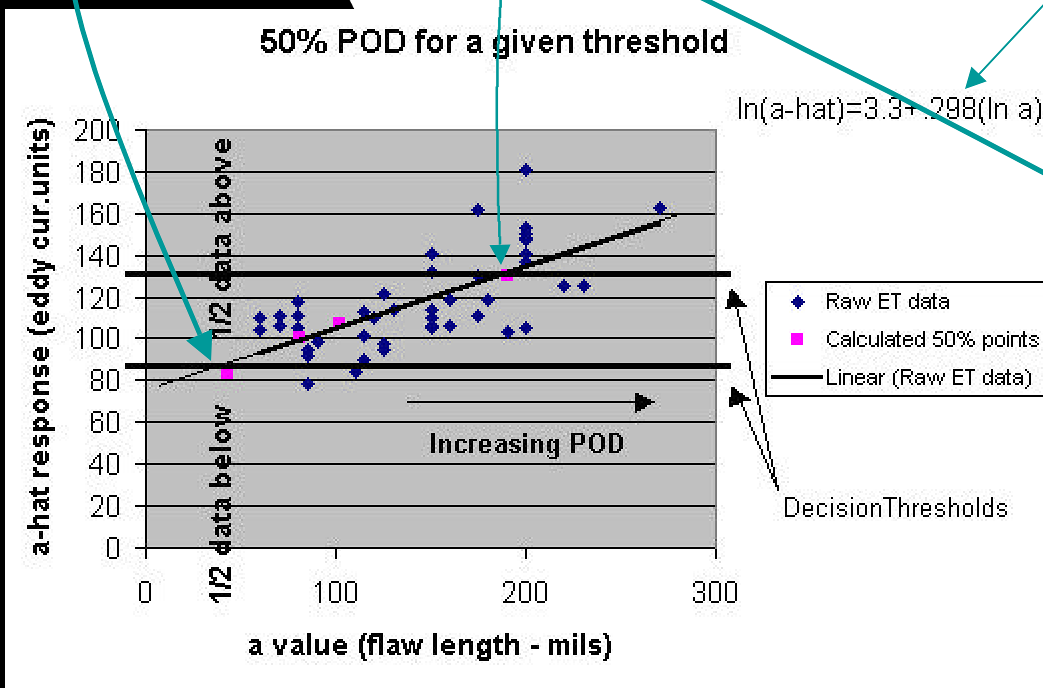
Follow-on activities

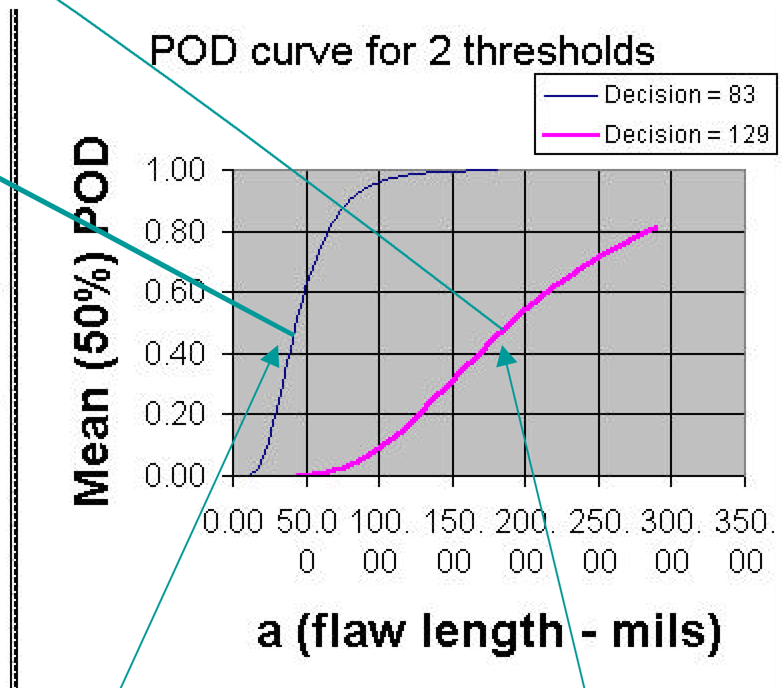
- Write up perspectives for publication in Materials Evaluation
- Compile index of reliability sources
- Vision for NDE data libraries
- Future workshop focus on review of assessments in context of agreed to guideline

What is a POD function?

Relation of system response to POD curve

Regression equation from A-hat.exe program





50% POD “point” for an 83 unit decision threshold

50% POD “point” for an 129 unit decision threshold