BACKGROUND MODEL-ASSISTED POD WORKING GROUP

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OUTLINE

- Steps Leading to the Formation of Model-Assisted POD Working Group

MODEL-ASSISTED POD WORKING GROUP SUMMARY OF STATUS

History

- Strawman Plan for a Consortium on Computational Nondestructive Evaluation (NDE) for Modeling POD (POD), NTIAC, 9/03
- A *Planning Meeting for the Formation of a Consortium on Computational NDE for Modeling POD* was organized by NTIAC on 11/18-19/03.
- An outcome of that meeting was the formation of a POD Working Group to establish next steps and serve as the basis for longer-term activities.
  - Iowa State University Center for NDE as coordinator
  - Success is needed early on to demonstrate progress
  - Possible to leverage the demonstrations of model-assisted POD determinations already done by ISU?

MODEL-ASSISTED POD WORKING GROUP SUMMARY OF STATUS

Following Steps

- Numerous subsequent discussions
- Pratt and Whitney has agreed to place some internal data developed in the context of POD determination for aircraft engines in the public sector which will save the Model-Assisted POD Working Group the time of repeating ground that had been already covered
- Meeting to be scheduled in September at which the engine demonstration would be presented and future actions defined.

MODEL-ASSISTED POD WORKING GROUP PROSPECTUS SUMMARY

Objective

- To promote the increased understanding, development and implementation of model-assisted POD methodologies

Background

- A broad community with interests in POD determination
- A forum to discuss and provide input on a wide variety of issues related to this emerging approach

MODEL-ASSISTED POD WORKING GROUP PROSPECTUS SUMMARY

Approach

Meet periodically and conduct the following activities:

- Discuss strategies for model-assisted POD determination
  - Empirical approaches, refined to with insight from physics-based models
  - Model-assisted methodologies based on flaw response
  - Model-assisted methodologies based on image data
- Discuss requirements for models to be used in POD studies
  - Accuracy expected of models
  - Extent of validation required
  - Strategies/requirements for determining input parameters

MODEL-ASSISTED POD WORKING GROUP PROSPECTUS SUMMARY

- Identify gaps that need to be addressed between state of the art physics-based models and real world problems
  - Accuracy expected of models
  - Extent of validation required
  - Strategies/requirements for determining input parameters
- Provide input regarding examples of specific problems that would demonstrate the utility of model-assisted POD activities
  - How models can be used to establish the acceptability of replacement inspection techniques, e.g., transition from single frequency eddy current methods to transient eddy current methods
  - Use of models to assist in the transfer the results of assessments under one set of conditions to a related set of conditions
  - Full POD determinations as required to meet lifing requirements

MODEL-ASSISTED POD WORKING GROUP PROSPECTUS SUMMARY

- Communicate the results of model-assisted POD demonstrations
  - The working group would not be expected to do the detailed work in these areas but rather serve as a sounding board and provide general input

MODEL-ASSISTED POD WORKING GROUP PROSPECTUS SUMMARY

Metric

The Model-Assisted POD Working Group will be considered a success if, during its duration, activities under a variety of programs lead to

- Draft protocols for model-assisted POD
- Draft requirements for model qualification for use in POD determination
- Model-assisted POD demonstrations

MODEL-ASSISTED POD WORKING GROUP PROSPECTUS SUMMARY

Duration

The Model-Assisted POD Working Group will be initially constituted for a period of 18 months

Output

A final report will be prepared summarizing the findings of the Model-assisted POD Working Group, including suggested

- Strategies for model-assisted POD determination
- Requirements for models to be used in POD determinations
- Examples of specific opportunities for future demonstrations
- Future directions

OUTLINE

- Steps Leading to the Formation of Model-Assisted POD Working Group
- Agenda for this Meeting

AGENDA
MODEL-ASSISTED POD WORKING GROUP
SEPTEMBER 23-24, 2004

<u>Thursday, September 23</u>

Noon - Box lunch

1:00 - Agency Perspective-AFRL, FAA, NASA
- Vision of the need for Model-Assisted Approaches to POD Determination

2:00 - Background-B. Thompson, ISU
- Steps leading to the formation of the Model-Assisted POD Working Group
- Agenda for this meeting
- Setting the technical stage

2:45 - Break

3:00 - Case Study of a Demonstration-K. Smith, Pratt and Whitney
- Model-Assisted POD determination for rotating components of aircraft engines

4:00 - Review of Prospectus-Attendees

4:30 - Discussion of Calibration Issues-Rummel, Nakagawa
- 3-Point calibration and demonstration of a possible role played by models in its implementation

5:30 - Adjourn

AGENDA
MODEL-ASSISTED POD WORKING GROUP
SEPTEMBER 23-24, 2004

Friday, September 24 – Meeting to be held at the AANC hanger

8:00 a.m. - Discussion of Major Issues Identified in the Prospectus-Attendees

- Strategies for Model-Assisted POD Determinations
- Requirements for Models

9:30 - Identification of Other Specific Potential Demonstrations (Interested parties to provide suggestions in advance for pre-reading)-Attendees

- Could include discussion of model-assisted methodologies based on either data that is analyzed on a pixel-by-pixel basis (as in examples discussed up to this point in the meeting) or image data (cases in which decisions are made on the results of the data in multiple pixels)

10:00 - Break

10:15 - Discussion of Future Directions-Break-out groups

11:00 - Reports-Break-out groups

11:30 - Next Steps-Attendees

12:00 - Adjourn

OUTLINE

- Steps Leading to the Formation of Model-Assisted POD Working Group
- Agenda for this Meeting
- Technical Issues

GENERAL REQUIREMENTS

Global Drivers

- New requirements driven by something old (aging equipment) and something new (inspection technologies)
- Move towards more quantitative risk management
- Need for cost effective means to determine POD
- Need for POD in cases where empirical approaches are impracticable

GENERAL REQUIREMENTS

Complex Cases Needing Better Treatment

- How to best do a POD study
- Desire to better handle cases with multiple factors influencing inspection
  - Area, aspect ratio and depth of delamination
  - Orientation, roughness, and closure of crack
  - Corrosion as influenced by morphology and poorly defined metric of "size"
- How to treat POD of image-based techniques
  - Decision based on data in multiple pixels

VISIONARY GOALS

Creation of POD "Equivalents" as Options to Formal POD Studies Through Informed Work Arounds*

- Abbreviated POD studies (with equivalent confidence)
- Extrapolated POD studies (with similar fidelity)
- Created POD studies (totally new studies)

Protocols ultimately needed to guide these applications

* J. Malas, Overview Talk #1, "Modeling of POD/Applications and Needs," Planning Meeting for the Formation of a Consortium on Computational NDE for Modeling POD, November 18-19, 2003, Austin, TX

POD IS AN INSPECTION METRIC USED AS

- An input to lifing/inspection interval decisions
- An input to the establishment of initial defect distributions (exceedance curves)
- An indicator of the relative effectiveness of various inspection strategies
- A measure of the relative performance of inspectors
- A measure of the fundamental capability of a measurement technique (independent of human factors)

Model-Assisted Approaches are of interest in reducing the time and costs of evaluating this metric in each of these scenarios

Absolute

Relative

MODEL-ASSISTED POD DETERMINATIONS HAVE THE ADDITIONAL BENEFITS OF SERVING AS A GUIDE TO PROCEDURE CHANGES THAT WILL IMPROVE POD

- Selecting the most important parameters to control in a given inspection
- Developing improved inspections

These benefits can have equal or greater long term benefits

A PROPOSED DEFINITION OF TERMS

SIMULATION

- Input parameters (values of the controlling variables)
- Physical assumptions about the process under investigation, such as
  - linearity
  - behavior of transducer
- Numerical solution of mathematical problems based on those assumptions
  - analytical approximations sometimes employed to gain computational speed
- Output predictions of:
  - flaw response amplitude
  - signal to noise ratio

MODEL

THE COMPLEXITY AND ABSOLUTE ACCURACY REQUIRED IN A SIMUMATION WILL VARY CONSIDERABLE FOR DIFFERENT APPLICATIONS

Two Limiting Cases:

- POD for lifing/inspection interval decisions

  ↓

  Hard number from highly accurate, sometimes complex model

- Developing improved inspections

  ↓

  Relative predictions from models which capture essential aspects of the physics of an inspection

Validation needed to fit purpose and span parameter space of interest

PRIORITIES IDENTIFIED IN AUSTIN

1. Validation of models (flaw response)
2. Totem pole of important factors
3. Design a multi-point calibration
4. POD transfer function; boundary conditions are important
5. NDE engineering tools
6. Model benchmarks
7. Demonstration with existing data

A VIEW FROM THE STATISTICS PERSPECTIVE

- NDE involves data generation and interpretation
- POD depends on the variability in NDE data
- Because it is practically impossible to empirically determine POD in all potential applications of NDE, we require the use of model to predict outside the range of available date
- The importance of physics-based models is that they provide
  - A framework to see how various factors affecting variability (POD) fit together
  - A reduction in the amount of expensive physical experimentation that needs to be done
  - A guide to sample fabrication
  - A necessary basis for extrapolation to new situations
- Limited experimentation will still be required to quantify those parts of the inspection process that are not yet understood well enough to have a physics-based model

PAST EFFORTS AT ISU: A BEGINNING OF A BROADER COMPILATION

	Problem	Modality	Sponsor	Model	Data	Validation	Factors Treated Empirically
1	Steam Generation Tubes	UT	NIST (Westinghouse)	Kirchhoff (Surface Breaking Cracks)	Field	—	Morphology & Scanning
2	Flat Plates	EC	NIST	BEM (Surface Breaking Cracks)	Laboratory	—	—
3	General	XR	NIST	XRSIM	Laboratory	—	Operator's Visual Acuity
4	Aircraft Engine Materials	UT	FAA ETC-Phase I	MOOT & Kirchhoff (FBH) & Born (SHA)	Laboratory	Â vs A (FBH)	Microstructure
5	Aircraft Engine Billets SHA	UT	FAA ETC-Phase I/II	Born	Production System	Production Data (Problems Identified)	Microstructure System/Operation
6	Riser Girth UT Welds	UT	ARDAMA (Oil Companies)	SOV (Pores) Kirchhoff (FBH)	—	—	—
7	Aircraft Engines Forgings	UT	PWA	Kirchhoff (FBH)	Field Personnel	Â vs A (FBH)	System/Operation

COMPILATIONS OF EXPERIMENTAL DATA/POD STUDY RESULTS

1. G. A. Matzkanin and W. D. Rummel, NDE Capabilities Data Book, NTIAC-DB-97-02.
2.
3.

DEMONSTRATION: ABSOLUTE PREDICTION OF POD FOR LIFING APPLICATIONS

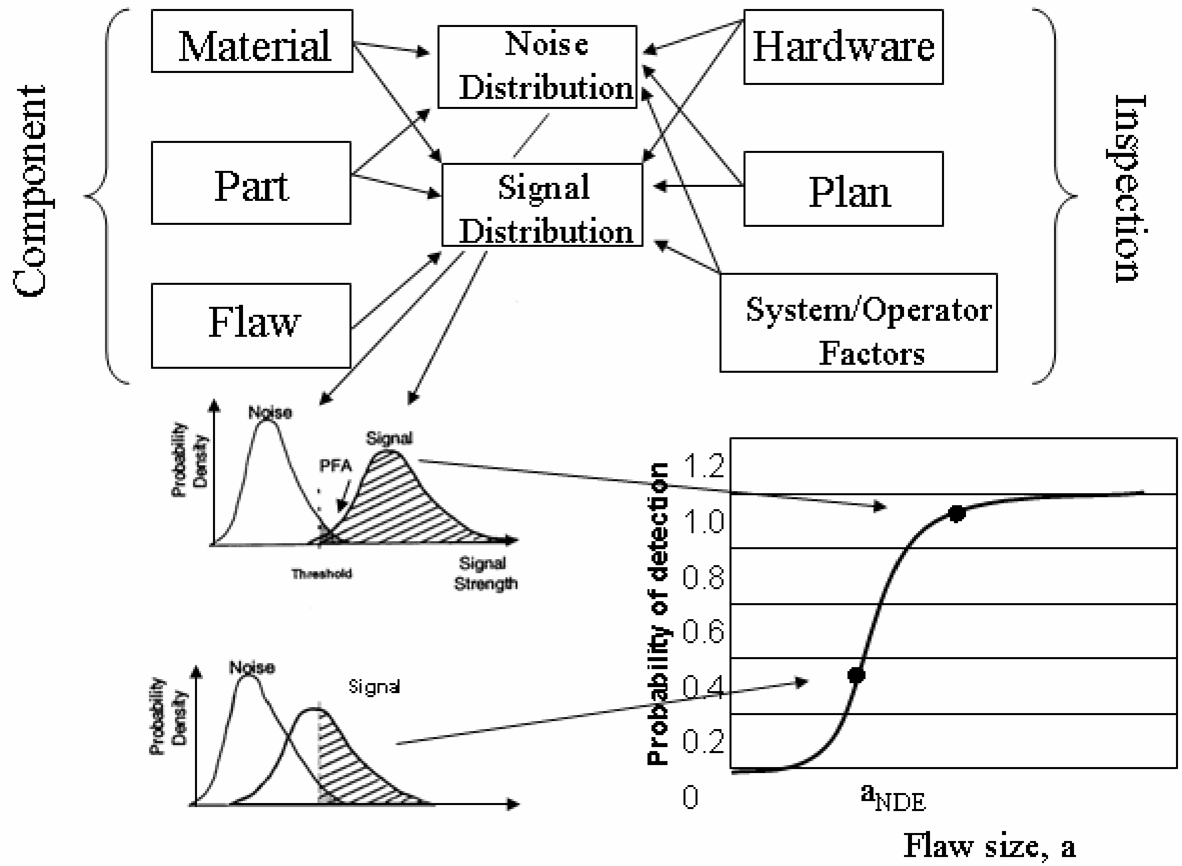
- The goal of the use of models on lifing applications is to reduce the
  - time
  - cost

  in POD determinations.
- Generally this means reduction in the required number of
  - samples
  - measurements

STATUS (LIFING APPLICATIONS)

- Significant progress has been made toward reaching these goals.
- A modular approach has been developed that makes heavy use of models.
- This has been shown to make it possible to reduce measurements and increase portability of POD determination.
  - limited empirical measurements aimed at assessing effects of such factors as human performance and flaw morphology will still be needed
- Even for these factors, models provide a systematic way of increasing understanding that will show the way to technique improvements.

POD MODULAR METHODOLOGY



ROLE OF MODELS

- Models can be used to predict signal strengths and those aspects of variability controlled by well-understood physical factors
- Variabilities can be broken into several categories
  - designed: built in to the inspection design √
  - intrinsic: controlled by material structure, e.g., backscattered noise √
  - extrinsic: controlled by deviation of inspection parameters from intended values *
    - operator set-up error
    - deviation of part from nominal geometry
    - deviation of probes from nominal characteristics
    - calibration errors
  - observational: human error in nonautomated applications (e.g., reading x-ray film)
  - flaw morphology

* For extrinsic variabilities
  - models can deal with these issues if the deviation of parameters from their nominal values is known
  - that information is often not available

STEPS TO GENERATE MODEL-ASSISTED POD*

- Identify controlling factors whose influence can be simulated using a physics based model
- Develop appropriate model
- Verify its accuracy in the laboratory through well controlled experiments
- Determine values of input parameter (or parameter ranges)appropriate to field application)
- Use simulation tool to predict mean response and those components of variability controlled by well understood physical phenomena
- Quantify additional sources of variability associated with components of variability not controlled by well understood physical phenomena and with variations of input parameters that cannot be fully controlled in the production environment
- Compute POD

*Adapted from R. Bruce Thompson, "Using Physical Models of the Testing Process in the Determination of Probability of Detection," Materials Evaluation, 59, pp. 861-865 (2001).