MINUTES
MODEL-ASSISTED POD MEETING
SEPTEMBER 22-23, 2005
ORLANDO, FLORIDA

Attendees:

A list of attendees may be found in File 1

Agenda:

The meeting agenda may be found in File 2.

Minutes:

The primary foci of this meeting were (a) the review of status of new demonstrations being undertaken in Canada and Australia and (b) the discussion of protocols for implementation of the XFN and FMA approaches.

Current Status: Thompson reviewed the past activities of the group. A copy of his PowerPoint presentation may be found in File 3.

Update on NRC-CNRC Program: DJ Butcher presented a status report on a Canadian Forces program to determine the eddy current POD for cracks under fasteners. Specifically, the goal is to validate the current minimal detectable crack size (a_{NDT}) in fastener holes representative of a box wing structure using Rotating Bolt Hole Eddy Current. An additional objective is to verify a POD model so that the POD of defects in similar structures can be interpolated. An overview of the program plan is presented, including the combined use of real cracks, manufactured cracks and EDM notches. This analysis will initially be done empirically. However, later in the program, the data will be used to verify a model-based POD approach. His presentation may be found in File 4.

Update of DSTO Program: On behalf of Cayt Harding of the Defense Science and Technology Organization (Australia), Thompson presented the slides from a talk that Harding had presented in August at the Review of Progress in Quantitative Nondestructive Evaluation. The talk was entitled "Model-Assisted POD for Ultrasonic Detection of Cracks at Fastener Holes". It was focused on the automated UT inspection for cracks in fastener holes in the F111 lower wing skin, a problem brought to a high level of visibility by a catastrophic failure during a wing fatigue life extension test. This was a progress report for a program in which the transfer function approach is being used. Harding argued that the biggest payoff of the MAPOD approach would be to replace estimates of detectable crack sizes (which are the basis for the majority of lifing decisions) rather than to replace full POD trials on representative specimens (which is not feasible for the F111 lower wing skin inspection under consideration). The effect of crack closure on the ultrasonic response was identified to be a significant factor. Her presentation may be found in File 5.

Next Iteration of XFN Protocol: Smith led an extended discussion of the next iteration of the Transfer Function (XFN) approach. The suggestion made by Spanel at the previous MAPOD Working Group meeting, that this protocol be developed as a part of the update of MIL HNDB 1823, NONDESTRUCTIVE EVALUATION SYSTEM RELIABILITY ASSESSMENT, provided a context for the discussions.

The first part of the discussion addressed a number of philosophical issues associated with the update of 1823 and how the MAPOD approaches might fit in. Some of the key points that were made are reproduced below.

- Regarding 1823 revision
    - The team that developed that document primarily had eddy current inspection for fatigue cracks in mind.
    - The document was written from the propulsion perspective.
    - In the update, equal attention should be given to ultrasonic inspection of internal defects including inclusions as well as voids and to airframes as well as engines.
    - More factors will need to be considered for the ultrasonic case. For example composition and morphology will be important.
    - Statistical algorithms need to be "spiffed up"; there are now a lot of standard ones that can be used.
    - It would be best if specific computer software were not a part of the document, just the algorithms to be used.
    - Examples (test cases) should be included to enable the user to test his/her software implementation of the algorithms against a known result.
    - We do not want to be too specific. The user should be allowed to use his/her brains since he/she knows more about the particular problem being examined than a committee writing the update of the handbook.
    - We should have a flow chart that is not too complicated.
    - We need to use a track change feature so that new parts can be easily identified. Brasche has volunteered to be the "keeper of the master document" which should facilitate the development of the new version.
    - Cautionary notes need to be added where applicable.
    - A new section will be needed for the XFN approach
- Regarding acceptance of new procedures
    - There is a need for regulator buy-in.
    - To gain industry's attention, an economic case must be developed.
        - A greater speed than that of current techniques will be one such argument
        - Enhanced ability to defend one self against suits is another argument.
        - The demonstrations reported by Pratt and Whitney were motivated by economics
    - What is needed to gain acceptance of the new procedures?
    - We will have to have protocols in place before acceptance can occur.

    - What sort of validation will be required?
    - How do we test the goodness of the transformation?
    - Dealing with morphology variations will be a problem.
- Regarding more general matters
    - We need to re-examine the issues that were raised in the Austin meeting to see how we are doing at addressing doubts.
    - We need to decide whether we are trying to develop a straw-man guideline or a consensus document for industry?
    - The idea of using models to replace intuitive "rules of thumb" is very attractive; regulators are now accepting the latter.
- Regarding the XFN approach
    - The baseline demonstration should be as close to the real part as possible

Smith then went over the outline of 1823. Yellow highlights were used to indicate regions in which he felt that major re-writes are needed and turquoise was used to indicate where minor re-writes are needed. The group discussed these suggestions. The document is provided as File 6.

Next Iteration of FMA Protocol: This discussion was led by Thompson. He first suggested that the FMA approach be thought about in a different way. Referring to the slide reproduced in File 7, he noted that the lower right hand box, test system variabilities (sometimes referred to as system/operator variability) has often been described as what one does to deal with the effects of those factors that are not controlled by well understood physical phenomena. From that perspective, it is something that one does at the end to catch what is left over. Thompson suggested that a different view could be taken to describe the same set of procedures. The test system variability box could be thought of as a baseline experiment to capture, in the simplest possible way, those variabilities that must be studied empirically. Physical models are then used to generalize (or transfer) the results of this experiment to another situation. From that perspective, the FMA approach can be viewed as having a structure that parallels that of the XFN approach. Instead of using experimental data as the basis of the transfer, one uses physics-based models.

To illustrate how this would be done, Thompson went over a flow chart of the FMA approach, as was previously discussed in the June, Orlando meeting. The relevant slides (the first 7) are reproduced here as File 8. A number of the comments that were made as a part of that discussion are noted below.

- Agree with box 2.
- The decision box numbered 3 should be re-phrased in the following way, "It is assumed that the person doing the test has a fundamental understanding of what he/she wishes to do. For each controlling factor, it should be asked 'Is a physics-based model applicable'"
    - It was noted that there is no right or wrong answer to this question. One team performing a POD studies might assign a given controlling factor to the empirical side while another might assign the same factor to the

model-based side. These could be equally valid approaches in the context of their overall approach to the problem.

- When generalizing 1823 to include the case of ultrasonic testing, it would be valuable to give examples of factors that might be considered.
- A recommendation should be included to enumerate both the engineering and statistical assumption in each study.
    - It is important to make the user aware of the assumptions in various approaches (statistical independence, linearity, …)
    - In cases of statistical analysis, the tools to be used should be clearly identified and justification given for their use in the particular circumstance. This might be on the basis of
        - Someone else's work
        - Particular assumptions made in the study in question
        - Papers in the literature
        - Statistical properties learned from simulations
- It would be nice, but probably impracticable to include cost considerations of empirical versus model-assisted approaches
    - Might best be dealt with separately
    - The answer is very application specific
        - Is also depends on whether one is engaged in a one-time only application or a series of related studies in which the model validation efforts would carry over to multiple POD determinations
- It must be noted that minimum needs are problem specific
- The situation in which people identify and use physics-based models has elements that are philosophically different from 1823
    - We need to define some new parameters to describe possible errors in predictions, analogous to those related to those associated with the amount of data in an empirical approach. For example, uncertainty bounds need to be considered.
    - It needs to be established how the range variations of input parameters would be established.
        - Sensitivity studies can play a key role in establishing the precision with which this range must be established for particular parameters.
            - This should show up in the logic
        - This in turn depends on a specification of the accuracy expected.
- We are essentially entering into a new realm and need a lot of information sources to guide users
    - Textbooks
    - Glossaries of terms
    - Etc
- We can not really say that this is a new way of doing things
    - Models have been used in various ways for a long time in admittedly simpler ways.
    - Whatever is done should allow for a graded approach, from simple uses of models, e.g. Snell's Law and Area-Amplitude relationships (such as have

been used in ultrasonics for some time) to more complex approaches such as is being considered now
  - The approach needs several levels
  - In order to gain widespread acceptance, one might want the new 1823 document to express the idea to the community that "You have been doing model-based studies for some time, here is how it can be done even better".
- The guidelines should be laid out in a way that all industry can access, not just those in aerospace
  - Currently, if someone is to follow 1823, they need to first get the software
  - The impression exists that the approach requires lots of dollars and samples
  - A graded approach is needed.
- It is important to lay out algorithms (e.g. how to do a DOE, how to plot results in a standard way, etc.) and decide where to put them in the document
  - Some algorithms ought to be in the Appendix and some are problem specific
  - However, we want to use references and avoid "writing a statistics book"
- We need to lay out a path that the reader can follow clearly without too much pain.

At the conclusion of this extended discussion, Thompson showed an outline of 1823, color coded to indicate which sections that he felt need modification. This was analogous to what Smith had done for the XFN approach, with the exception that a higher-level outline was used. This is shown as File 9.

FAA Load and Fatigue Studies as a Possible Demonstration Venue: Bode described the current status of a program in which a retired B727 passenger aircraft (operated by Delta Airlines) was subject to destructive evaluation and extended fatigue testing. It is now in a period of continued testing and inspection of some panels containing lap joints and cracks in fuselage skins around rivets. The objectives of the current program are to assess the capabilities of current and emerging NDE techniques, to characterize multi-site damage, to increase that MSD in selected sections through extended fatigue testing, to develop analysis methods to predict the extent of MSD at any point in time, and to create a searchable database and distribute for public use. Ways in which this structure could be used to validate the POD tools were discussed; with one of the key questions asked was whether the probes used were available for characterization. Bode's presentation is attached as file 10.

Other Possible Demonstrations/Funding Opportunities: Malas discussed future opportunities using the slides included as File 11. These summarize both demonstrations that are underway and new opportunities. He noted that there is a huge implication in this new, model-assisted way of determining POD. For example if one had more confidence in POD numbers, one could reduce safety factors. Moving a_{NDE} from ½ to 2/3 would have a huge implication and might supersede some human factor issues. (He noted that KARTA is conducting a study to try to identify the characteristics of the best and worst inspectors). Probabilistic risk assessment is becoming more widely used in the Air Force and NDE is a key input. There is also work underway to try to better define crack size distributions. He noted that some of the current problems are reaching the four-star level, that there are a number of possible funding routes opening up and made a strong request for white papers, ASAP, based on broad teaming and participation. These would be used to define possible responses to these opportunities. The white papers should be aimed at demonstrating technical feasibility on problems involve cracks under fasteners or cracks in turbine disks and should include a rough order of magnitude estimate of program costs.

Malas also expressed the belief that the real payoff would be with the transfer function approach and that the full model-assisted approach would evolve with time. He also noted that there will be a significant need for new sources of information such as textbooks, papers, and the like. He suggested that meetings discussing focused development of 1823 and new demonstrations of model-assisted approaches be separated so that the group could move most quickly.

Buynak presented an overview of issues related to the field assessment POD in airframe problems, using the slides attached as File 12. Included was the discussion of a system, attributed to Dave Campbell, intended to associate a degree of difficulty with the extent to which the capability of various techniques are degraded in the field by the influence of such effects as human factors, equipment, and inspection conditions in the field. One idea being discussed is to cut down inspection intervals (based on POD under ideal conditions) in accordance with this degree of difficulty. He gave an example of an assumed inspection baseline and described ideas that are being developed to obtain improved estimates of this baseline.

Future Directions:

The meeting closed with a discussion of future meeting topics and how to develop a focused effort on the rewriting of 1823. It was suggested that separate meetings be held to drill into 1823 and to discuss demonstration examples of MAPOD.

A team was established to serve as Associate Editors in the rewriting of 1823. This included Annis, Smith, Thompson, Spencer, Forsyth and Brasche.

Action Items:

Update of 1823

- Place minutes on the web-Thompson-12/1
- Email comments on minutes back to Thompson-all-12/15
- Suggest sections in need of update to Thompson-all-12/15
- Prepare a draft of update-Associate Editors-2/15

Formulation of an Integrated Program

- Organize a meeting to discuss how to leverage various capabilities, teaming prospects, and funding opportunities into a comprehensive program-Malas

Organization of Next MAPOD Meeting

- Thompson to organize next general MAPOD session, to focus on continued discussions of demonstrations, as a sequel to the Aging Aircraft meeting, late in the week of March 6.