MINUTES
MODEL-ASSISTED POD WORKING GROUP MEETING
OCTOBER 26-27, 2006
HOUSTON, TEXAS

Attendees:

A list of attendees may be found as File 1.

Agenda:

The meeting agenda may be found in File 2.

Minutes:

BACKGROUND

Thompson summarized the general background for new participants. Slides may be found in File 3.

As more specific background, it should be noted that at the previous MAPOD Working Group Meeting, held March 9-10, 2006 in Atlanta, Georgia, there was an extended discussion, led by David Forsyth, about what would be required to demonstrate the effectiveness of the MAPOD concept. An action item from that meeting was for Forsyth to develop a white paper based on that discussion, forward that white paper to the group for comment/input, and then submit the white paper to AFRL for evaluation. That process was completed between the March, 2006 and October, 2006 MAPOD Working Group meetings, and that white paper provided a background for the October, 2006 meeting. It is attached in its current form as File 4.

The white paper points out that transfer functions can be envisioned for three categories of activities, namely

- Transferring from notch response to laboratory grown crack response to naturally occurring crack response.
- Transferring from cracks occurring in a simple geometry, e.g. a flat plate, to cracks occurring in a more complex geometry, e.g. a field component
- Transferring from what would be observed in the laboratory to what would be observed in the depot and then the field.

The primary purpose of the October, 2006 meeting was to develop a detailed plan for the first bullet, transferring notch response to crack response.

DISCUSSION OF ISSUES RELATED TO TRANSFER FUNCTIONS FROM NOTCHES TO CRACKS

Knopp presented a summary of some of the early literature on the relative responses of cracks versus notches. He specifically mentioned that

- Rummel, Moulder, and Nakagawa had reported on the relative responses of cracks and slots in 1990 (Review of Progress in QNDE, 10A, p. 277, 1991). In that work, they identified the similarities and differences in the responses of crack and notches. The emphasized that, although notches have many uses in set-up, calibration and demonstration of area coverage, "they DO NOT produce eddy current response signals that are equivalent to cracks of equal size."
- Ratz (Boeing) presented a paper in 1991 (ATA NDT Forum, Long Beach, California, September, 1991) discussing the significance of the eddy current crack/slot response to airplane inspection. He acknowledges the difference in the eddy current response of cracks versus notches and that this difference may have an influence on efforts to quantify (size) cracks. However, he argued that present practice to use EDM slots for eddy current instrumentation sensitivity calibration would not result in the failure to detect a required crack.
- Hagemaier, Collingwood, and Nguyen (McDonnell Douglas) presented a paper at the same meeting (ATA NDT Forum, Long Beach, California, September, 1991) reporting the results of a series of scans of cracks and notches in 7075-T6 aluminum. They concluded that there was good agreement between the two as long as the notch width was sufficiently small.
- Auld, Muennemann, and Winslow (J. Nondestr. Eval. 2, 1, 1981) presented a general theory for the eddy current response for two-dimensional and three-dimensional open and closed surface breaking cracks. Differences in the responses of cracks and notches ware reported, with an important component being the flaw opening response that increases with frequency. Supporting experiments are reported.

Copies of some of the Ratz and Hagemaier papers, not generally available can be found in File 5 (Ratz) and File 6 (Hagemaier).

Thompson initiated the discussion of the factors that control the transfer function relating cracks to notches by reviewing some material that he had presented at the 2nd MAPOD meeting, held February 4, 2005 in Palm Springs, California. This material may be found in File 7. The purpose of this discussion was to identify all factors that might need to be considered in developing a transfer function from notches to cracks in a particular application. Included was a discussion of different mechanisms that influence the relative responses of crack and notches for both ultrasonic and eddy current measurements. The results of that discussion are summarized in File 8.

Comments concerning the relative response of cracks and notches that were made during the discussion included the following. Note that this is a snapshot of the discussion to capture the issues discussed and not a compilation of group consensus.

- The crack response is often seen to be greater than the notch response in regular inspection of aluminum structures.
    - As a reason, it was argued that, in such inspections, one uses the quadrature component of the signals, away from the lift-off direction, where notch volume effects are suppressed.
- In contrast, in magnitude, the notch signal is always larder than the signal of the same-size crack.
    - This of often observed in standard inspections of engine components, where the signal magnitude is used in place of the quadrature, because the separation between lift-off and defect signals is not achievable in such inspection conditions.
- Theoretical work examined the effect of ligature that would produce localized points of conduction across the crack face
    - Experiments related to this have been conducted by Junker at Westinghouse
- An EDM notch is a better approximation to a large crack than a small crack and for cracks on the opposite side of a plate than the same side
- A lot of work has been done in the fracture community to study the effects of contact between the crack faces (closure) on crack propagation
    - Some important investigators were Elbert, Buck, Suresh (MIT), Neumann (NASA and then Mississippi State)
- Factors differentiating the response of cracks and notches are different
    - For engines and airframes
    - For surface and subsurface cracks

Lindgren led a discussion of goals for the notch/crack work:

- Intermediate goal: Transfer function from cracks to notches in simple laboratory samples
    - John Brausch, AFRL, is having a set of samples prepared in aluminum, titanium and steel.
    - These would include surface breaking cracks grown in constant amplitude tension-tension loading as well as some notches
    - The idea would be to show that the general concept of a transfer function works in this sample set
    - Elements of a plan would include
        - Obtaining samples from Brausch
        - Making eddy current and ultrasonic measurements
        - Comparing results to theory
        - Repeating under load (to remove the effects of contacting asperities)
        - Again comparing to theory
    - Action items included
        - Laying out this plan in greater detail
        - Determining who would like to contribute

        - Completing the plan by the time of ASIP 2006
    - Rummel volunteered to provide input on how to make the samples.
        - He noted that these types of experiments provide an opportunity to determine how crack growth conditions place bounds on crack responses and influence the variance of that response.
- Long term goal: Apply these concepts to the ultrasonic inspection of the Rainbow Fitting in the C130 Hercules.
    - The existence of a POD set with EDM notches at Warner Robbins would be a key step.
    - An important advantage of this particular system is that there is more information in the public domain than would normally be the case because of multi-country and civilian use and that samples are already in existence.

DEMONSTRATION PROGRAMS

Forsyth and Thompson led a discussion of a demonstration program, building on the ideas that appear in the white paper that has been developed by Forsyth. The results of that discussion appear in File 9.

Lindgren helped the group prioritize goals. This include the following three items in order of priority

- Construction of a transfer function based on controlled experiments
- Determination of the degree to which physics-based models for UT and EC can predict this transfer function
    - It was noted that a given crack could be studied from the same side with eddy currents and the opposite side with ultrasonics, providing an opportunity to directly compare the effects of crack morphology on the two modalities.
- Application of these results to a two-layer problem, the Rainbow fitting

UPDATE AND DISCUSSION ON SIGNIFICANT EFFORTS

Khan provided an update on the NRC-DND POD project.

Annis reported on the status of the update of MIL HDBK 1823. This is due to be completed early in 2007 and he requested any further input by Christmas, 2006.

Intergraph (Vanderall and Miener) provided a report on their newly initiated activities that will support the MAPOD effort.

It was reported that NIAR was funded to do work aimed at manufacturing A-10 bolt hole specimens and studying human factors issues related to their inspection.

Malas emphasized the importance of preparing monographs to support the development/implementation of the MAPOD concept. He noted that MAPOD is very

important to the Air Force since cracks are being found in older aircraft and solutions are needed. However, it is important to develop the science and technology in parallel with the demonstration programs such as will be conducted on the C-130 Rainbow Fitting.

He saw the MAPOD effort as having four major ingredients

- Knowledgeable experts
- Monographs to serve as an educational resource
    - POD
    - Human Factors
    - Equipment
    - Inspection Systems Design
- Significant demonstrations
- 1823 update

Next Meeting:

The next meeting will be held as a sequel to the Aging Aircraft meeting on Friday, April 20th in Palm Springs, California.