The Air Force Nondestructive Inspection Improvement Program

2010 ATA NDT Forum
20 – 23 September, Albuquerque

Sponsored by USAF - AFRL/RX
Government POC: Damaso A Carreon  AFRLRXSST

David Forsyth², Mark Gehlen³, Jeff Guthrie¹, Mark Keiser², Ronald Kent¹, Michael Morgan¹, Carlos Pairazaman³, Darren Stamper¹, Damaso Carreon⁴
1. Alion 2. TRI/Austin 3. UniWest 4. USAF
Overview

- Why?
- Program Description
- Typical Findings
- Solutions
  - Technical Orders
  - Technology Insertion
  - Verification and Validation
- Conclusions
- Acknowledgements
Why?

• One of many efforts in continual improvement of Nondestructive Inspection (NDI) performance at United States Air Force (USAF) depots and field units.

• Inspection technique documents (Technical Orders or TO’s), equipment anywhere from 10 to > 40 years old.
  – Known issues, but lack of available resources to deal with them
  – Personnel are busy getting the aircraft back into service!
Why –
Technical Orders - example

• Written instructions are to inspect x number of fasteners here!

• But there’s a lot more than x!
Why – POD and POI

• POD = Probability Of Detection

• Given:
  – Defined inspection technique
  – Defined discontinuity type on defined inspection target

• Probability Of Detection is a function describing the detection of the discontinuity as a function of its size
Why –  
POD and POI

• POI = Probability Of Inspection
  – Even less clear than POD.
  – Is inspection performed at all?
  – Is inspection performed correctly?

• EFFECT ON RISK OF POI < 1.0 IS SIGNIFICANT
Why –
How to affect POI

• Is inspection being done?

• Is inspection being done correctly?
  – Does T.O. clearly indicate location, scan plan, inspection technique?

NDI Improvement Program
Overview

• Why?
• Program Description
• Typical Findings
• Solutions
  – Technical Orders
  – Technology Insertion
  – Verification and Validation
• Conclusions
• Acknowledgements
Program Description –
The NDI Improvement Program

• USAF fleet Aircraft Structural Integrity Program (ASIP) managers tasked to identify, rank control points on aircraft based on structural integrity parameters:
  – Damage tolerance life exceeded by fleet leader?
  – Single load path?
  – Cracks found in fleet?

• Some fleets have control points with “yes” to all the above
• Already delivered:
  – 90 inspection techniques have been audited based upon the prioritization
    • Re-written procedures provided to USAF to modify existing Technical Orders (TO’s)
  – Two new “probe kits” have been delivered to provide improved POD/POI
    • Targets chosen with USAF guidance to provide highest ROI
Program Description – Approach

• Experienced inspectors (ASNT Level III or better in at least one related discipline) witness actual inspections at USAF depot/field sites.

• Standard, simple semi-quantitative audit form to capture results and provide direction for improvement.
Overview

• Why?
• Program Description
• Typical Findings
• Solutions
  – Technical Orders
  – Technology Insertion
  – Verification and Validation
• Conclusions
• Acknowledgements
Typical Findings

• There are a number of common (occasional) issues with TOs.
  – Wrong references in procedure to other applicable paragraphs in T.O.
  – No clear description where to inspect using the text description
  – No clear description where to inspect using the drawings

• There are a number of control points where an assumed NDI capability is better than the capability defined in the new USAF guidelines.
  – This can have severe impact on operations.
    • See Harris et al. at ASIP 2009
Typical Findings

• There are categories of inspections that are common across many fleets, that could be improved with new probes.
  – Raised head fasteners
  – Edges
  – Radii
  – Flat area scanning
Overview

• Why?
• Program Description
• Typical Findings
• Solutions
  – Technical Orders
  – Technology Insertion
  – Verification and Validation
• Conclusions
• Acknowledgements
Solutions – Technical Orders

- Working with AF personnel to fix simple issues through established processes of TO updates.
  - TO’s provided to the AF NDI Managers in format ready for insertion
  - by end of calendar 2010, over 200 technical orders audited, updated
Solutions – Technology Insertion

• USAF guidelines allow smaller “detectable crack size” for use of probes with reduced degrees of freedom in movement

• New eddy current probe designs being used in other AF programs.
  – modified for cross-cutting application

• Probes compatible with existing USAF standard equipment.
Solutions – Technology Insertion - Raised Head Fastener Inspection
Solutions – Technology Insertion – Raised Head Fastener Probe
Modified US-2103 Swivel Head Edge Probe
(Shoe rotated 90 degrees)
Solutions – Technology Insertion –
Edge and Surface Inspection Probe Kit
Scan back and forth across radius indexing 0.125 on each pass.
Solutions - Verification and Validation of New Probe Designs

• Verify
  – That probes work (form, fit, function) on the identified opportunities.
    • For example, tight access may eliminate possibility to use new probes.

• Validate
  – Estimate POD.
Audience Participation
## Raised Fastener Recommendations

<table>
<thead>
<tr>
<th>Description</th>
<th>Tested on air frame (yes/no)</th>
<th>Inspection area accessible with fastener probe [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>cap to web at WS 92</td>
<td>No</td>
<td>N/A</td>
</tr>
<tr>
<td>5 to 90</td>
<td>No</td>
<td>N/A</td>
</tr>
<tr>
<td>I Web Attach, WS 1050</td>
<td>Yes</td>
<td>50</td>
</tr>
<tr>
<td>ord Attach, WS 1055-1085</td>
<td>Yes</td>
<td>100</td>
</tr>
<tr>
<td>h Attach, WS 1070-1080</td>
<td>Yes</td>
<td>50</td>
</tr>
<tr>
<td>F665</td>
<td>Yes</td>
<td>50</td>
</tr>
<tr>
<td>h, WS 889</td>
<td>Yes</td>
<td>50</td>
</tr>
<tr>
<td>Attach, WS 780</td>
<td>Yes</td>
<td>100</td>
</tr>
<tr>
<td>Attach, WS 780</td>
<td>Yes</td>
<td>100</td>
</tr>
<tr>
<td>n WL 280 &amp; 364 &amp; Horizontal</td>
<td>No*</td>
<td>N/A</td>
</tr>
<tr>
<td>Dow Fitting Tangs, L/R</td>
<td>No*</td>
<td>N/A</td>
</tr>
<tr>
<td>Panel Risers at Rib Cap-to-Panel 126, 180, 249, 266, 283, 300, and 420, L/R</td>
<td>No*</td>
<td>N/A</td>
</tr>
</tbody>
</table>
• What is validation for NDI?
  – Probability Of Detection (POD)!

• How to get it?
  – MIL-HDBK-1823

• Can use
  – per MIL-HDBK-1823:
    • Similarity
    • Models
    • Empirical Studies
Solutions – Verification and Validation

- New edition of MIL-HDBK-1823 explicitly allows for use of models, similarity in POD estimation.
  - Minor changes to probes already validated require minimal effort to validate.
  - Each diameter of raised fastener probe does not require a “full POD study”.
  - More cost-effective validation than fully empirical approach.
Solutions – Verification and Validation – NDI Performance metrics

- Probability of Detection (POD)
- “Probability of Inspection” (POI)
- False Call Rate
- Cost/time to perform inspection
  - Equipment capital and ongoing
  - Disassembly requirements for access
  - Inspector time
Solutions – Verification and Validation - Ongoing

• Using existing USAF specimen set from previous studies.
  – Can directly compare results to a large set of pencil probe results.
    • POD, POI, FCR, time, cost
Solutions – Verification and Validation - Ongoing

- USAF QAPA Specimen and Pencil Probe
Solutions – Verification and Validation - Ongoing

• USAF QAPA Specimen and RHF Probe
• Multiple USAF inspectors at each depot will inspect the QAPA specimens with the RFH probes.
  – Trial modeled after the QAPA study.
Overview

• Why?
• Program Description
• Typical Findings
• Solutions
  – Technical Orders
  – Technology Insertion
  – Verification and Validation
• Conclusions
• Acknowledgements
Conclusions

• USAF guidance for reliably detectable crack size, pencil probe around a fastener head:
  – 0.200” of exposed crack length

• RHF probe preliminary results
  – ~ 0.100” of exposed crack length

• Reduced degrees of freedom of movement of the RHF probe may translate into reduced inspector to inspector variability.
  – This is key!
Conclusions - POD


**GUIDELINES FOR PENCIL PROBE CAPABILITY**

**ASSUMED CAPABILITY**

Hypothetical capability of 0.100” plus covered length provides 1900 FH re-inspection interval
Conclusions - POI

• What makes an inspection not valid?
  – Not done.
  – Not done correctly.
    • Equipment, calibration, probe manipulation, recording
Conclusions - POI

• How did your two circles look?

• Published literature indicates POI is real in large POD trials.
  – “The estimated background miss rates from the 45 inspections ranged from 0 to 0.168, with an overall average of 0.024”
  – Floyd Spencer, Don Schurman, Reliability Assessment at Airline Inspection Facilities Volume III: Results of an Eddy Current Inspection Reliability Experiment, DOT/FAA/CT-92/12, III, May 1995
Conclusions - POI

- Hard (impossible?) to know how this translates to field results.

- We will evaluate POI as part of the validation study.

- RHF probe should improve some of the contributing factors to POI problems
  - Probe tilt out of spec
  - Repetitive, tiring, manually difficult
Conclusions - FCR

• Very few false calls in the QAPA study.

• False call rate in field is unknown.

• We will evaluate the FCR in the validation study.
Conclusions - Time

• We will measure the time required for the RHF probe inspection on the QAPA specimens and compare to the pencil probe inspection.
Conclusions - Cost

• RHF probes are more expensive than pencil probes.

• RHF probes use the current USAF ET equipment.

• RHF probes will require some additional training.
  – Draft TO and draft training package are being delivered to USAF as part of this effort.

• Reduced inspection intervals are a big cost benefit!
Conclusions – Misc.

• Experimental work shows no effect of fastener material on RHF probes.
  – Non-conductive, Al, Ti, Steel

• Will evaluate other substrate materials
  – Using similarity approach of MIL-HDBK-1823

• Edge probes and area probes also to be validated.
Summary

• Program continues with a “spiral” approach.
  – Review SOFI/ALC identified procedures.
  – Implement improvement in TOs.
  – Identify opportunities for technology insertion.
  – Verify and Validate new technology.
  – Implement new technology into depot and field.
Acknowledgements

• Program Oversight from the AF NDI Office (AFRL/RXSST)

• Funded by the Air Force Materiel Command’s Depot Maintenance Operations Division (HQ AFMC /A4DM)

• Great cooperation from USAF personnel at all levels.
  – Oklahoma City Air Logistics Center (OC-ALC)
  – Warner Robins Air Logistics Center (WR-ALC)
  – Ogden Air Logistics Center (OO-ALC)
  – Aeronautical Systems Center - Engineering Directorate (ASC/ENFS)
  – Air Force Research Laboratory’s Material Integrity Branch (AFRL/RXSA)
  – Air Force Research Laboratory’s Nondestructive Evaluation Branch (AFRL/RXLP)
Public Service Announcement

• DoD funded resource you can access:
  – [http://ammtiac.alionscience.com](http://ammtiac.alionscience.com)

• DoD DDR&E is funding an update to the (formerly NTIAC) POD Handbook.
  – please contact me for further information
  – please contact me if you have data that can be included
  – dforsyth@tri-austin.com
  – 512-263-2101