Advancements on the Adoption of SHM Damage Detection Technologies into Embraer Aircraft Maintenance Procedures

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Currently

photo: West Star Aviation
Aircraft Maintenance

What was already been accomplished

2009  FAA, EASA & ANAC accepted SHM into Commercial Aviation Maintenance Programs

During the International MRB Policy Board Meeting (A4A MSG-3)

Mar 31st - Apr 03rd, 2009  –  São José dos Campos/Brazil
Review and final acceptance
S-SHM Proposal
Aircraft Maintenance

Future?

**Scheduled-SHM (S-SHM):**
the use of SHM devices for inspections at an interval set at a fixed schedule

**Automated-SHM (A-SHM):**
relies on the SHM system to inform maintenance personnel that action must take place

**Maintenance Actions On-Demand**

Source: SAE/ARP 6461 and A4A MSG-3
SHM Technologies

SHM Damage Detection Technologies studied by Embraer R&D

- Acoustic Emission (AE)
- Electro-Mechanical Impedance (EMI)
- Fiber Bragg Gratings (FBG)
- Comparative Vacuum Monitoring (CVM)
- Lamb Waves (LW)
- Meandering Winding Magnetometer (MWM)
Comparative Vacuum Monitoring (CVM)

Ground Tests since 2007

R&T Metallic Barrel Test

• Continuous monitoring
Comparative Vacuum Monitoring (CVM)

Ground Tests since 2007

E-Jets Full Scale Fatigue Test

- 260 Sensors Installed (Silicone and Sheet Sensors)
- Periodic/Scheduled inspections

Wing Stub

Fuselage Splice

Window Frame

Forward Fuselage
Comparative Vacuum Monitoring (CVM)

Flight Tests

- On-ground scheduled data acquisition using the PM200 equipment

* Courtesy Structural Monitoring Systems Ltd.
Lamb Waves (LW)

Ground Tests since 2008

Laboratory Tests

- Thickness reduction in aeronautical aluminum
- Delamination detection in CFRP
Lamb Waves (LW)

Ground Tests since 2008

E-Jets Full Scale Fatigue Test

- Periodic inspections

Rearward Fuselage

Wing Spar
Lamb Waves (LW)

Flight Tests

- On-ground scheduled data acquisition

* Courtesy Acellent Technologies Inc.
Scheduled-SHM

What do we need?

- Technical Feasibility
- Consistent Business Case
- Approved in a Certification Process
- Compatible with Continued Airworthiness Requirements
- Acceptability by Operators

SUCCESSFUL

SHM SOLUTION

Luis Santos (Embraer), based on:


Qualification Project

Objectives

• Qualification (formal process) of two SHM damage detection technologies
  • Comparative Vacuum Monitoring (CVM)
  • Lamb Waves (LW)

• Laboratory Tests for Environmental/Durability and Probability of Detection (POD)

• Installation and monitoring of sensors and cables into in-service aircraft

• Close consultation of ANAC (Brazilian Civil Aviation Agency)
Qualification Project

Laboratory Tests – Detection Capability

Comparative Vacuum Monitoring (CVM)

Al 7475
t=2.54mm

Comprehensive Vacuum Monitoring

Lamb Waves (LW)

Al 2024
t=2.032mm

Lamb Waves
Qualification Project

Laboratory Tests – Detection Capability

- To determine crack length that corresponds to a level of 90% Probability of Detection with 95% Confidence (90/95 POD) – One-sided Tolerance Interval method

Comparative Vacuum Monitoring (CVM)

Lamb Waves (LW)
Qualification Project

Laboratory Tests – Environmental

• Environmental/Durability Tests
Qualification Project

In-service Aircraft

• Service Bulletins for the installation of CVM and LW sensors and cables into **Azul Airlines** aircraft
• 5 Aircraft (installation from 4Q/2013 to 1Q/2016)
• Data acquisition: 18 months
Qualification Project

Installation into 3 of 5 Aircraft during Maintenance Checks

CVM
4 sensors per a/c

LW
6 sensors per a/c
Qualification Project

Installation into 2 of 5 Aircraft during Maintenance Checks

- **CVM**: 10 sensors per a/c
- **LW**: 4 sensors per a/c
Qualification Project

Periodic Data Acquisition during overnight interventions
Qualification Project

Periodic Data Acquisition during overnight interventions

• CVM and LW S-SHM Systems
Qualification Project

In-service Aircraft Results

Comparative Vacuum Monitoring (CVM)
How can S-SHM replace traditional inspection procedures?

S-SHM procedure replacing a SDI

Without SHM

- High downtime due to assembly/disassembly
- Complex/Time Consuming Inspections
- High probability of induced damage during inspections

With SHM

- Minimal downtime/simple access panel removals
- Simple/quick inspection procedures (‘plug in play’)
- No induced damage in the inspection areas

*SDI: Special Detailed Inspection
A traditional type of inspection according to the A4A MSG-3 methodology

Just an alternative means of compliance (AMOC)
Qualification Project

Conclusions

• Probability of Detection (POD) data was obtained with laboratory tests for both CVM and LW SHM systems, according to the requirements. Environmental and Durability test data were also obtained. In general, results corroborate the expected durability of sensors, cables and connectors.

• Objectives of the In-service (Azul) Aircraft test phase:
  • For CVM – demonstration of survivability and stability of the technology
  • For LW – data acquisition is still underway, but preliminary results are very positive

• The Qualification Project had and still has close consultation of ANAC regulatory agency – A formal process for Scheduled-SHM was established
Qualification Project

Conclusions

• Lamb Waves technology is more complex when compared to CVM. Embraer is moving forward with the study of the technology, including filling the gaps for maturation. A POD was obtained and data acquired during in-service aircraft tests are presenting good response. Lamb Waves demonstrates high potential to be the next SHM technology to be available for inspection procedures.

• POD data was also obtained for CVM. During in-service aircraft tests CVM response values were stable over time indicating good performance. For hotspot inspections CVM technology can be used as a new inspection approach (S-SHM), as an alternative means of compliance, to provide facilitated damage detection, allowing the reduction of maintenance costs for current and future aircraft.
Thank you