Enabling Condition Based Maintenance for Helicopters

Keynote Lecture for
7th European Workshop on Structural Health Monitoring
2nd European Conference of Prognostics and Health Management (PHM) Society
Nantes, 9th of July 2014

Falk Hoffmann, Airbus Helicopters Deutschland GmbH
OUTLOOK

➤ The Airbus Group

➤ Airbus Helicopters

➤ Recent Highlights & Innovations

➤ Condition Based Maintenance for H/C

➤ Current & Future Challenges in the field of PHM and SHM
The Airbus Group

- Globally leading commercial aircraft manufacturer
- Order book coverage >8 years

- Leading helicopter manufacturer
- Accounting for 1/3 of the global helicopter fleet

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Recent Highlights & Innovations

- High Speed & Long Range
- Blue Pulse Demonstrator
- Optionally Piloted Vehicle (OPV)
High Speed – Long Range

Idea & Use Cases:
✓ Combine the best of helicopter & airplane (vertical take off and high speed)
✓ Technology demonstrator based on AS365 Dauphin
✓ Reduce acoustic footprint & CO2 emission compared to conventional helicopter
✓ Time efficiency for Rescue & Emergency
✓ Air Taxi...

Achievements:
✓ Concept demonstration by integration of existing components
✓ 2013 speed record: of 255knots in LF

Key messages
Thinking without limits!
Blue Pulse - Innovative rotor system using active flap technology and flight regime recognition

Key messages
Multi-functional, smart active system becomes reality...

Achievements:
✓ Vibrations reduced by > 50% in level flight and approach
✓ BVI noise reduced by 50% (est. 2-3 EPNdB in approach under certification condition)
✓ Active in-flight tracking demonstrated
Optionally Piloted Vehicle (OPV) - Manned and Unmanned Flight

Use Cases:
- Observation and search
- Firefighting/Disaster management in remote areas (e.g. Fukushima)
- Heavy load cargo (e.g. sling load)
- Weapon carrier

Achievements:
- Designed to ensure safety during unmanned test flight close to populated area
- Manual engines start & shut down (by pilot)
- Automatic take off & landing initiated from GCS (Ground Control Station)
- Automatic hover flight with limited speed inputs from GCS
- Automatic and autonomous flight plan execution
- **Autonomous reaction in case of system degradation**
- Flight plan change via GCS
- External load

Key messages
- Diagnosis & Prognosis as key enabler for autonomous systems

ETG/HG Falk Hoffmann / Enabling CBM for Helicopters / 1.0 / Pilot Keynote Lecture

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Condition Based Maintenance (CBM) for Helicopters

- What & Why?
- CBM Development Process
- AH Health Management System
- CBM success factors & challenges
Condition Based Maintenance

→ Maintenance in dependency of the helicopter health:

“Healthy” helicopters continue operation

Helicopters with anomalies require maintenance

Objectives:

– Prevention of incidents
– “Maintenance only if necessary”
CBM a Challenge?

Aircraft Maintenance

- Operational goals
- Condition-Based Maintenance
  - Condition Monitoring
    - Sensors
    - Signal processing
    - Fault diagnostics
    - Prognostics
    - Data management

Requirements (technical, economical & operational)

- Operational reliability
- Structural integrity
- Scheduled inspections

Airworthiness regulations
- Development costs
- Operator requirements

Operational goals

- Reduced operating costs
- Increased availability
- Increased operating safety

Airworthiness regulations
- Development costs
- Operator requirements

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Costs

- **Life Cycle Costs**
  - all costs during the product life cycle

- **Direct Operating Costs (DOC)**

**DOC Break Down EC135 P3**

- CBM can reduce Direct Maintenance Costs + Labor Costs
  - **EC135** → Light twin-engine H/C (3t), EMS configuration, ~ 500FH/year
    - After 11 years in-service, DMC reach ~ 50% of H/C sales price
  
  - **EC225** → Heavy h/c (11t), Offshore, ~1000FH/year
    - After ~7 years in service, DMC reach ~ 50% of h/c sales price
Incident Analysis

Original Scenario

- **Severe** TDS bearing damage
- Long drive shaft (consequential) damage
- Cost calculation of ISIRG268
  - $\Sigma$ Maintenance Costs* ~5k€
- **Safety impact**!
  - Worst case grounding time **6 days**
  - Worst case grounding costs* 70k€...140k€
- Authority investigations
- Transportation costs ? €
- **Manufacturer involvement** ? €

* Labor costs ~ 110€/hour

** Scenario with HUMS **

- TDS bearing damage (early diagnosis of degradation)
- **NO** Long drive shaft damage
- Cost calculation of ISIRG268 1500,- €
- **NO** Safety impact !
  - Worst case grounding time ~0.5 days
  - Worst case grounding costs* ~3k€...12k€
- **NO** Authority investigations
- **NO** Transportation Costs
- **NO** Manufacturer involvement

* Grounding costs ~ 3k€/hour

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Generic CBM Development Process

**INPUTS**
- Design reliability assessment
- (Past) Service Experience
- In-service fault findings
- CMS’ data corresponding to in-service fault findings
- CMS’ and degradation data from testing

**ACTIONS**
- Identify relevant faults
- Define degradation limits
- Evaluate maintenance need
- Evaluate fault detection performance
- Modify detection method and/or damage metric

**OUTCOMES**
- Initial scheduled maintenance program
- Optimized scheduled inspection
- Scheduled major inspection
- Scheduled minor inspection
- Candidate for online inspection

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ONBOARD Helicopter Usage, Health & Flight Data Management System

AmC* – Aircraft Management Computer
DMAU – Dynamic Monitoring Acquisition Unit

* Embedded SW for UMS, HFDM & Failure Management

Airborne System

Vehicle and Engine Sensors

MFD

DTD

DMAU / HMS

Accelerometer

Rotor Speed

28VDC

Ground Station

Compact Flash

Usage Files

Health Files

Flight Data Files

Failure Code Files

Ethernet Connection

Configuration

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Ground Helicopter Usage, Health & Flight Data Management System

CUSTOMERS
Maintenance & Operation Information system

Data Collection
- On event
- Daily Flow
- Mi term Flow

Update:
- Documentation
- Thresholds

Back Office
CRM
Fault cases
Data Analysis
Front Office
- HUMS Hot Line
- Data Analysis

DATA CENTER

MARMS Ground Station

VHM
UMS
FDR
CMMS

WebHUMS
CRM
Fault cases
Fleet status

Automatic feedback

USAGE Report
HEALTH Report

IS Extraction

Manual

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CBM Success Factors & Challenges

1. Data Quality
   • Test Data from benches or h/c zero → representativeness...
   • In-service HUMS/HFDM data → SNR, variability...
   • Maintenance Data → fault type, fault severity, pictures, component life...

2. Data Quantity → the more the better

3. HUMS Coverage & Performance

4. Quality of Diagnostic & Prognostics Techniques
   • Degradation modeling, fault type, fault severity, RUL...

5. Part Maintainability and Inspection Methods
Future Trends & Challenges

- CBM certification
- Multi-level data capitalization & data fusion for planning of: mission, resources, maintenance, spare part logistics
- Configuration management
- Secured wireless on ground communication
- Digital sensors and sensor networks
- Integration of robust, energy harvesting sensor technologies in the rotating system
- Mission assurance, sense & respond concepts, real-time decision making
Thank You for Your Attention