Mechanical Components Diagnostics Research

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Tribology & Mechanical Components Branch

*Drive System Team Mission*

- Conduct basic research and technology development on mechanical components and drive systems.

- Results lead to first principle understanding of complex phenomena of component or system operation in normal and extreme conditions.

- Technology transfer results in improved operation efficiency and safety of Rotary Wing Aircraft.
Technologies for Propulsion – Drive Systems

• **Advanced Drive System Components and Systems**
  – Multi / variable speed drives
  – Improved gear alloys
  – Enhanced gear operation / control
  – Composite material application to dynamic components
  – Modified geometry gear design, bearings & system arrangements

• **Lubrication Technology**
  – Improved loss-of-lubrication (longer time, lighter weight,…)
  – Reduced power loss – windage drag reduction

• **Condition Based Maintenance (CBM)**
  – Improved detection techniques – i.e. non-metallic sensors
  – Improved data algorithms
  – Validated methods – rotorcraft field verification
What is CBM?

• **Condition Based Maintenance:**
  – Application and integration of processes, technologies and knowledge via a systems approach to improve aircraft reliability and maintenance effectiveness [1]

• **Goals:**
  – Reduce maintenance burden
  – Increase aircraft availability
  – Improve flight safety
  – Reduce cost
RW CBM Focus - Propulsion

Propulsion System Health
- Improved detection techniques
- Improved diagnostic algorithms
  - Multi-sensor data fusion
  - Performance metrics
  - Damage magnitude assessment
- Validated methods – rotorcraft field verification
  - Test methods representative of fielded faults
- Future prognostic algorithms
  - Damage life prediction models – predict remaining useful life

Structural Health & Exceedance Monitoring
- Correlate aircraft operational parameters to component life.

Research enabled through partnerships between NASA, FAA and Army
Condition Indicators (CI)

- A measure of detectable phenomena, derived from sensors that show a change in physical properties related to a specific failure mode or fault. [1]

Vibration-based Mechanical Component Diagnostics

Raw Data Snapshot ➔ Algorithm ➔ Condition Indicator (CI)

\[
M8A = \frac{N^4 \sum_{i=1}^{k=N} (d_i - \bar{d})^6}{\left( \sum_{i=1}^{k=N} (d_i - \bar{d})^2 \right)^4}
\]
**Objective:**
Demonstrate diagnostics to detect gear and bearing planetary system faults in main-rotor gearbox

**Approach:**
Develop algorithms from seeded fault tests on the OH-58 main-rotor transmission (AATD/Bell OSST)
Planetary Fault Detection

**Status:**
- Project complete
- Successfully identified the presence and location of a planet tooth crack in a blind test
- Sun tooth cracks were not detected with this method.
Objective:
Develop MEMS wireless sensor for fault detection in rotorcraft transmission applications

Approach:
- Develop MEMS vibration-monitoring accelerometer, microcontroller conditioner, wireless transmitter, and receiving unit for data collection.
- Mount directly on helicopter transmission component of interest to measure abnormalities and faults.

Status:
- OH-58 pinion tooth crack detection test completed after 110 hrs.
- MEMS sensors operating successfully, detected tooth fracture.
- MEMS tests for planetary planned.
SBIR – Embedded Data Acquisition Tools for Rotorcraft HUMS (Ridgetop)

Fractured OH-58 pinion tooth

Last Day of Testing

Accelerometer "R"

Accelerometer "T1"

Accelerometer "T2"

MEMS Accelerometers
CI Performance in the Lab

Objective:
- Develop CI validation methods in the lab that better represent fielded faults
- Identify limitations using rig tests

Approach:
- Perform tests in GRC Rig
- Evaluate CIs during naturally occurring faults.
- Define Fault: Class, Mode, Degree
- Document fault progression
- Verify (CI) Response
- Correlate faulted helicopter gears
CI Performance in a Helicopter

CI Performance/Sensitivity to Specific Gear Wear Modes

CI vs. Gear Wear Analysis (50%)

<table>
<thead>
<tr>
<th>Gear Wear Mode</th>
<th>Condition Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGMA 1010</td>
<td></td>
</tr>
<tr>
<td>Input Pinion</td>
<td>Out_DA1</td>
</tr>
<tr>
<td></td>
<td>In_DA1</td>
</tr>
</tbody>
</table>

NGB Tail 04, Input Pinion SI

- 4.2 micropitting
- 4.3.2 progressive
- 4.3.3 flake
- 4.3.4 spalling
- 6.1 Brittle Fracture

Part Replacement Date

Mean CI Value

Negative mean CI change.

±10% uncertainty.

10 to 25% mean CI change.

25 to 50% mean CI change.
Objective:
• Conduct seeded fault experiments of both standard (steel rolling element) bearings and hybrid (ceramic rolling element) bearings to examine the difference in damage vibration and propagation
• Determine the effectiveness of currently used flight sensors as compared to higher bandwidth research sensors

Approach:
• Obtain healthy data under normal loading conditions, seed fault and propagate under normal conditions
• Seed damage using a hardness tester and monitor the vibration change during propagation under normal loading

Status:
• One hybrid and one steel test completed
• Steel bearing ran for 50 hours after material removal
• Test rig load path concerns
• A fixture has been designed to make the process of seeding bearing faults with a hardness tester in angular contact bearings more repeatable
Questions
