Benefits of Usage Monitoring and T&E in Fleet Management of U.S. Army Helicopters

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Army Force Mod Helicopters are at Mid Life

- Average design age of Army Force Mod Helicopters: ~30 years

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Entered Service</th>
<th>Design Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH-47</td>
<td>1961</td>
<td>44+ years</td>
</tr>
<tr>
<td>UH-60</td>
<td>1978</td>
<td>27+ years</td>
</tr>
<tr>
<td>AH-64</td>
<td>1984</td>
<td>21+ years</td>
</tr>
</tbody>
</table>

- 2000 of 3000 Force Mod aircraft are slated to be rebuilt and upgraded and remain in service beyond 2030.
Objective: Protect safety.
Goal: Ensure six-9s of reliability.

Intent:
Conservative assumption of fatigue damage accumulation.

Reality:
Does not address operational usage related degradation.

Design usage spectrum
- Design flight regimes
- % time in regimes

Cyclic load & stress for each flight regime
- Determined by flight test
- Conservative (2 of six 9s)

Stress vs Life
- Life = mean minus 3σ
- Conservative (3 of six 9s)

Assumes severe usage
Conservative (1 of six 9s)
Usage Monitoring and T&E Facilitate Understanding of Maintenance Drivers

- Replacement for cause --
  - Fatigue cracks
  - Delamination
  - Impact damage
  - Corrosion
  - Wear

- Usage Related Degradation --
  - Environmental Corrosion
  - Stress Relaxation
  - NDI Measurements
  - Supported by Destructive Test
  - Statistical Sampling

- Note: Operational location environments --
  - Elevation
  - Desert
  - Tropical
  - Cold
  - Salt
  are important usage parameters.
Army Helicopter CSIs Fall Far Short of Achieving Design Life Expectations

Based upon 96 AH-64A/D, CH-47D/F, UH-60A/L CSI Part Nos.

US Army Actuals

- 25%, $217M
- 33%, $188M
- ?=$29M
- ?=$163M

Assumption: All components will achieve the service life of those in current maintenance database.

Parts & Labor Cost:

100%, $54M

Monitored Life:

216%, $25M

Design Life:

?=$29M
FLL CSI Management Process

1. **T&E Selected Parts to Ensure Continued Safety**
   - Info Feedback (Lessons Learned)

2. **For Cause**
   - Design Flight Hrs

3. **Inspect Part**
   - Anomalies

4. **Rework Part?**
   - Yes
   - No

5. **Return Part to Inventory with Usage & NDI Info**

6. **Discard Part**

7. **Monitor Part Usage History**

8. **NDI Parts in Field**

- CSI life managed by --
  - Flight hours
  - Usage information
  - Test verification

Seldom Occurs!
XRD is a rapid method for measuring residual stress.
- Non-contact
- Reliable
- Non-destructive
- Quantitative

Residual stress characterization relates to –
- Crack initiation
- Stress corrosion cracking
- Crack propagation
- Fatigue life

XRD applies to helicopter critical safety items:
- Dynamic components
- Drivetrain components
- Engines components
- Airframe & landing gear

XRD measurement of residual stress facilitates –
- Awareness of degradation
- Improved safety
- Informed decisions
- Reduced cost
Residual Stress Measurement Using X-Ray Diffraction (XRD)

- XRD can be applied in the field or at the depot.
- **Field usage: Portable iXRD®**
  - Rugged
  - Small
  - Lightweight
  - Easy to use
  - Fast
  - Adaptable software

- **Depot usage: Laboratory LXRD®**
  - Heavy duty
  - Accurate
  - Repeatable
  - Fast
  - Flexible
  - Automated data generation
Residual Stress Measurement Using X-Ray Diffraction (XRD)

✔ Mix & match maps
  - Residual stress
  - Peak width
  - Hardness
  - Principal stress
  - Stress tensors
  . . . More

✔ Before & after maps
  - Check pre- and post-process
  - Compare new & used
  - Track life cycle

✔ Result displays
  - Customize reports
  - Identify hidden trends
  - Pinpoint hotspots
Residual Stress Measurement Using X-Ray Diffraction (XRD)

- Residual stress affects:
  - Fracture loads
  - Crack opening thresholds
  - Fatigue life

Fracture Load vs Temperature

Crack Opening vs Loading Stress

Stress vs Cycles to Failure
Residual Stress Measurement Using X-Ray Diffraction (XRD)

- Stress corrosion cracking requires:
  - A susceptible material
  - A corrosive environment
  - Tensile stress

- Tensile stresses can be detected with XRD
- Reject parts returned or reworked

[Stress vs Distance to Weld Centerline graph]
Residual Stress Measurement Using X-Ray Diffraction (XRD)

✓ Compare effects of stress relief cycle:
  - Thermal stress relief
  - VSR (vibratory stress relief)

![Graph](image-url)

**HR 1020 Residual Stress vs Distance from Weld Toe**

- Stress (ksi) vs Distance (mm)
- Data points for pre and post VSR and TSR averages
Residual Stress Measurement Using X-Ray Diffraction (XRD)

- Track Residual Stress
- Obtain XRD Data Over Time
- Map Stress Distributions
- Track Degradation
- Relate To Usage
- Augment Decisions
  - Rework part?
  - Retire part?
  - Continue using part?
  - Modify usage?
- Results:
  - Reduced Cost
  - Increased Readiness
  - Enhanced Safety

Average Stress:

Unused Disk: 0 Cycles

Used Disk: 8078 Cycles
XRDWIN2.0™ Software
Sample Results

✓ Residual Stress Measurements
✓ Triaxial Stress Measurements
✓ Automated Stress Mappings
✓ Utilities
  ➢ Principal stress calculator
  ➢ Effective depth of x-ray penetration
  ➢ Remote access through network
  ➢ Interactive help wizard
✓ Add-In Modules
  ➢ Pole-figure module
  ➢ Expert System module
  ➢ Database Management module
  ➢ Inline Inspection stress module
  ➢ Strain Gauge Monitor module
Summary

✓ US Army Force Mod helicopters are at mid life.
✓ Many critical items achieve a fraction of their design life.
✓ There is the potential to improve the outcomes.
✓ Requires understanding of usage-related degradation.
  ➢ Monitor critical item usage.
  ➢ Track critical item degradation.
  ➢ Relate degradation to usage.
✓ Intervene by making informed decisions:
  ➢ Rework part?
  ➢ Retire part?
  ➢ Continue using part?
  ➢ Modify usage?
✓ Achieve benefits:
  ➢ Improve maintenance
  ➢ Increase readiness
  ➢ Enhance safety
  ➢ Reduce cost