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The challenges of structural airworthiness management within Defence

Presented by DASA and QinetiQ

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Overview

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2. Military vs Civilian Usage
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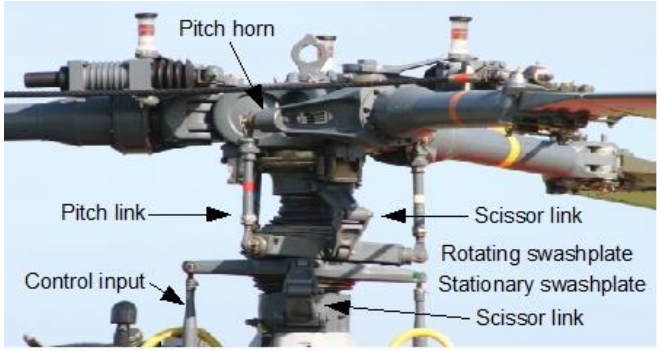
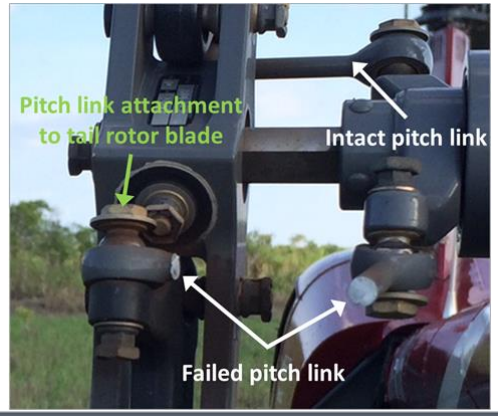
Helicopter Fatigue Accrual

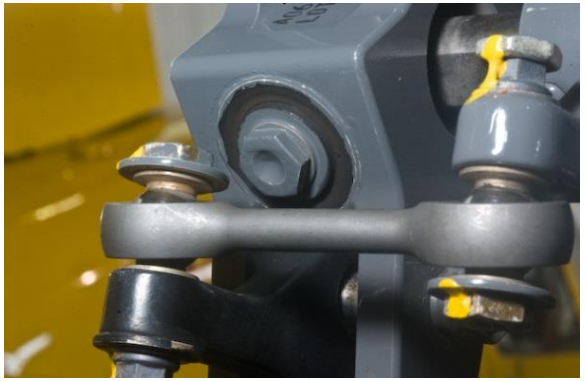
- Helicopter structure fatigues (or accumulates fatigue damage) as a result of the cyclic loads the helicopter structure experiences throughout its life

- The helicopter structure consists of the entire airframe and all dynamic components. However, the helicopter structure we focus on are those parts of the airframe and dynamic components that require particular attention due to their consequence of failure & susceptibility to fatigue damage

- In Defence, this subset of helicopter structure that accrues fatigue is referred to as *helicopter critical parts*







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Helicopter Fatigue Accrual (continued)

- With that in mind, when we talk about fatigue accrual on helicopters, we're referring to the accumulation of fatigue damage prior to crack initiation, i.e. safe life.

- OEMs translate accumulated fatigue damage into theoretical fatigue lives for selected helicopter structure. OEMs do this using their own methodologies and a baseline for how the helicopter is intended to be flown in service.

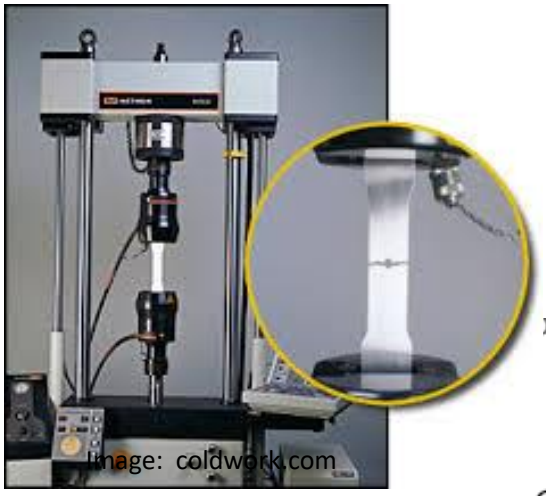


Image: coldwork.com

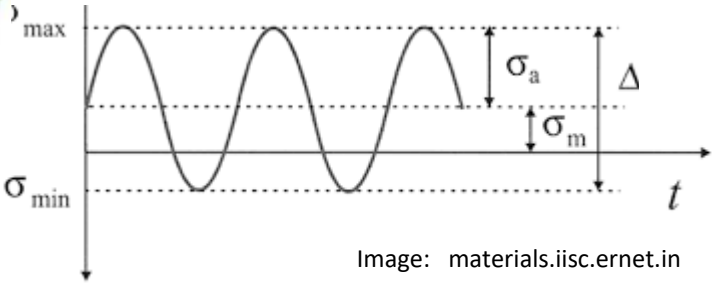


Image: materials.iisc.ernet.in

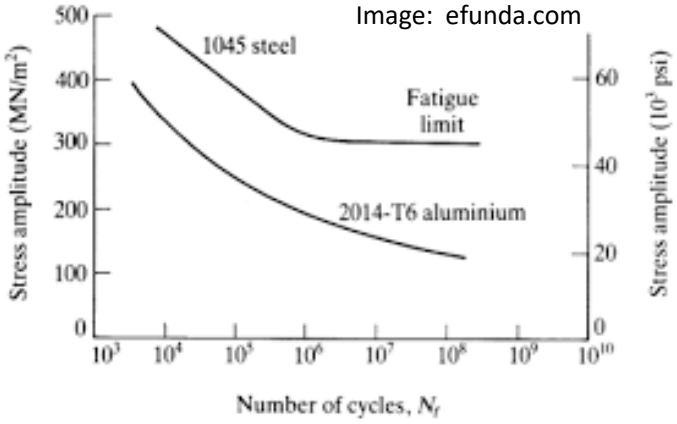
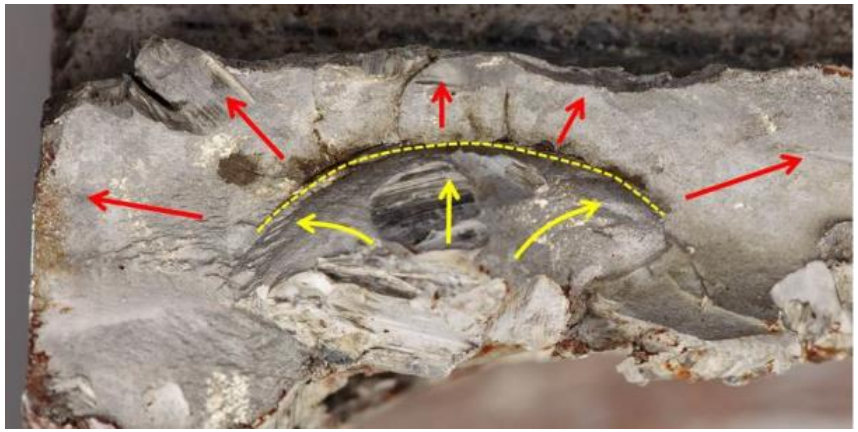


Image: efunda.com

Helicopter Fatigue Accrual (continued)

Airbus Helicopter H225
Second Stage Planet Gear
Fatigue Failure in 2016



Robinson R22 Main Rotor Blade
Failure in 2003

Military vs Civilian Usage

The difference between:

- Flying in a repeated, consistent manner for the vast majority of the aircraft's service life, and

- Flying with multiple configurations within one fleet, disproportionate amount of time in harsh environmental conditions and the nature of the fleets operations varying routinely

What about aircraft that are used for training and aircrew currency flight?

Military vs Civilian Usage (continued)

- The AS350 Type is one of the most widely used helicopters in history
- It was originally type certified under civil processes and received a civil type certification for civilian roles from the French Authority and from the US FAA in the 1970's
- The ADF adopted the Squirrel as a military helicopter, mostly accepting the existing civil Type Certification
- Only one known fatigue related incident

Image: Everestnews.com

Military vs Civilian Usage (continued)

OEMs and structural integrity management

- Are you flying in congruence with OEM assumptions
- Are you confident that you are not introducing loads on your helicopter structure that were not accounted for within OEM assumptions
- A recent exercise conducted by Vencore, Sikorsky and US Army to recalculate certain life limits for Army UH-60 variants using in-service usage data to update the Design Usage Spectrum

Component	Potential Life Change	
	UH-60A/L	UH-60M
MR Shaft Extender	50%	504%
MR Shaft	6%	233%
MR Hub	-4%	183%
MR Blade Cuff	-20%	17%
MR Rotating Swashplate	-25%	4%
MGB Housing	0%	36%

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Challenges of Usage Monitoring

Typical Usage Parameters	Collected under OEM instructions	Required for good usage characterisation
Flight hours	✓	✓
Landings	*Sometimes*	✓
Engine Cycles	✓	✓
Time in different airspeed, weight and altitude bands	χ	✓
Frequency of pull-up / push-over manoeuvres	χ	✓
Frequency of cyclic reversals	χ	✓
Frequency of turns at different bank angle	χ	✓
Time in hover IGE/OGE	χ	✓
Time in sideways/rearwards flight	χ	✓
Etc…	χ	✓

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Challenges of Usage Monitoring (continued)

- Is it sufficient to collect solely usage parameters prescribed by the OEM?
- How do you know if your helicopter is being exposed to a higher level of risk of failure as a result of unmonitored usage (above flight hours)?
- What additional usage parameters should you be collecting?
- What methods should be used to collect additional usage parameters? What is feasible?


Image: reddit.com

Model	Tail Numbers	Army Flight Hours
UH-60A/L	867	106,523
UH-60M	318	40,096

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Actual Usage vs Design Usage Spectrum (DUS)

- How do we know which DUS parameters/regimes are most damaging to focus on?
- Variability in impact of different regimes on different components means less than 100% comparison can be problematic
- How do we know the usage parameters we record are representative of the DUS parameters/regimes the OEM used in developing helicopter structure fatigue lives?
- Can regime recognition alleviate these challenges?
  - Yes PROVIDED you have the required documentation or OEM support to develop your RR…which is another challenge in itself
- Regime recognition basically takes out all the guess work
  - Relieves pilot work load
  - Improves accuracy and removes ‘a level’ of risk and/or otherwise necessary conservatism

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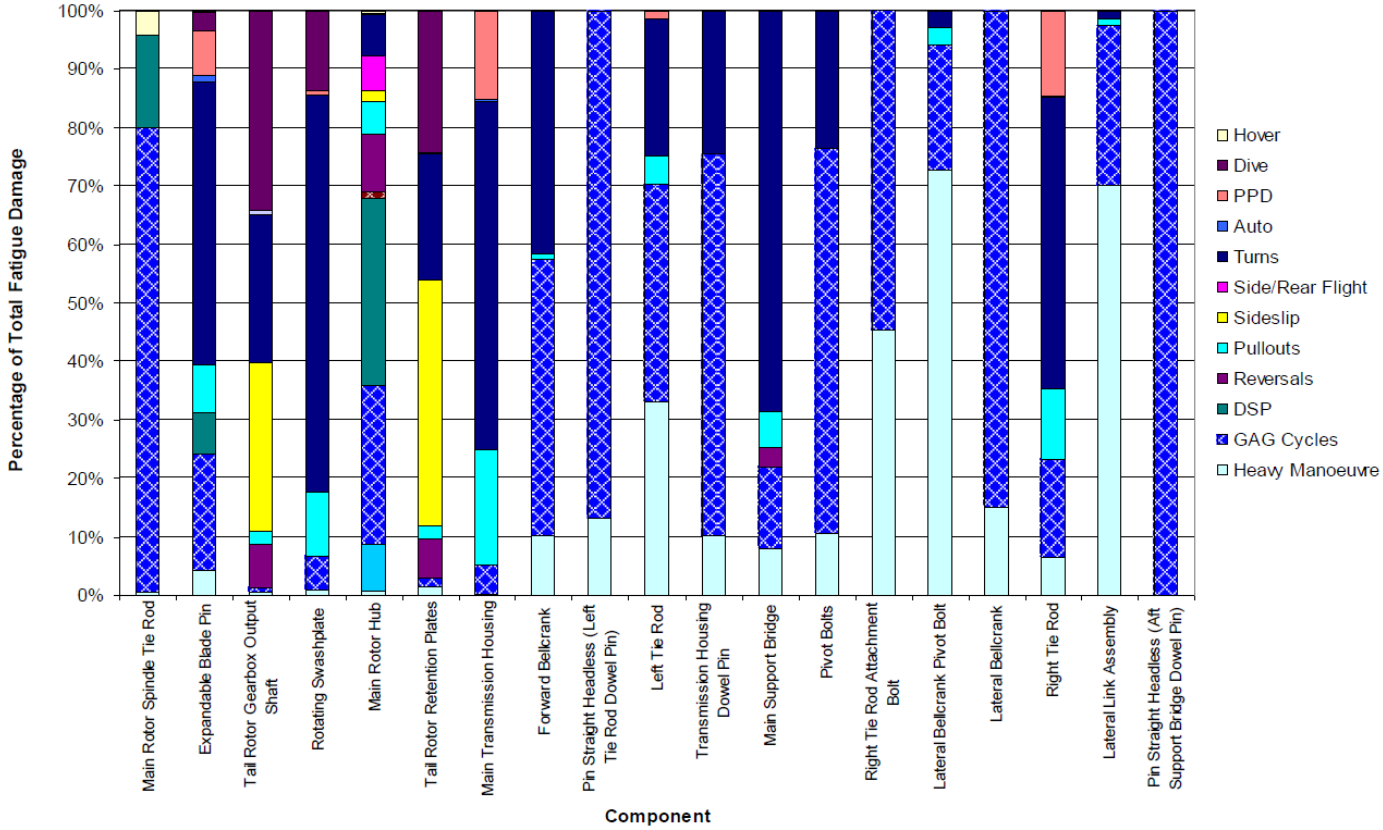
Actual Usage vs DUS (continued)



Ideal picture having overcome challenges of comparing recorded usage to design usage spectrum: All helicopter critical parts are accounted for. All damaging manoeuveres are recorded and all fatigue damage rates are known!

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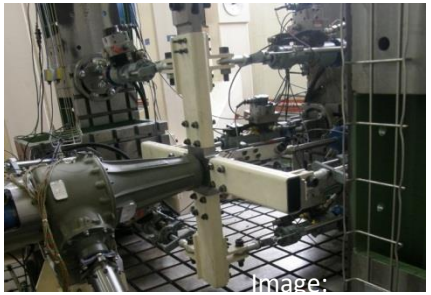
Implications of Fatigue Accrual

The main area of risk is **usage monitoring**

Environmental Degradation (ED) is a factor but OEM usually provides clear guidelines to manage ED from a safety perspective



Acceptable safety levels:

- Comparison against the design usage spectrum
- Within your helicopter's type certification basis (TCB) – e.g. was the OEM's design compliant against an airworthiness requirement that accounted for ship operations?
- Outside of your helicopter's TCB but within the helicopter's Type Design – e.g. did the OEM take into account loads representative of ship operations?

Implications of Fatigue Accrual (continued)

Fatigue accrual rates when transferring helicopter critical parts between different models:

- From Chinook CH-47D to CH-47F Foxtrot
- From S-70B-2 Seahawk Bravo to MH-60R Seahawk Romeo

Implications of Fatigue Accrual (continued)

RAN AS350BA Squirrel Fleet example:

- The ADF procured Squirrels in 1983
- Usage monitoring did not commence until 2001
- Usage was manually recorded by pilots following each mission

Image: airforce-technology.com

Image: defenceconnect.com.au

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Squirrel usage monitoring case study

This case study will run through:

- Early days of Squirrel usage monitoring (UM)
- Retrospective UM deficiencies that were identified
- Squirrel UM at its peak - pseudo ‘manual ‘regime recognition
- The importance of OEM support that the ADF lacked
- Why we accepted the sub-optimal Squirrel UM system as ‘good enough’ without progressing further


Image: australianflying.com.au

Squirrel usage monitoring case study

Early days of Squirrel usage monitoring (UM)

- ADF Squirrels commenced flying in 1984, however the only usage parameter that was tracked between 1984 and 2000 was airframe hours
- Usage monitoring on Squirrel helicopters began on May 2001
- It consisted of a simple parametric usage monitoring form (EE360 Form) that was manually populated by pilots upon completion of each sortie
- The usage parameters on the form were determined by Rotary Wing Section (RWS) (former HSI section) and DSTO by using analysis of the OEM DUS
- Between 2001 and 2009, the RWS section conducted a number of structural integrity activities and assessments which culminated into a decision in 2009, to conduct a critical review of the Squirrel UM system

Squirrel usage monitoring case study

UM deficiencies

- A two part critical review of the Squirrel usage monitoring system (UMS) was completed in 2010 and 2011, and found the Squirrel UMS to be substandard/ineffective
- Main finding was that we were unable to provide a confident characterisation of the fleet's usage for several reasons
- The review identified manoeuvres possibly being flown that may not have even been considered by the OEM in the DUS or in flight loads survey
- The EE360 compilation instructions, which allowed for both under and over-recording of different parameters depending on interpretation
- Insufficient resources also lead to a lack of a routine review process and Squirrel stakeholder engagement, which would have provided opportunities to identify certain issues much earlier

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Squirrel usage monitoring case study

UM deficiencies (continued)

- System devolved over time
- Training platform – “flies very consistent sorties…right?”
- Implemented lookup data depending on training code selected
- No validation recorded/available
- No regular re-validation
- Limited OEM support and limited access to OEM data to make our own judgements or verify assumptions

Squirrel usage monitoring case study

Squirrel UM at its peak - pseudo 'manual' regime recognition

- The critical usage monitoring review produced valuable recommendations.
- Most recommendations over the next several years were supported and "adopted":
  - Recording rotor starts
  - OEM confirmation of representative baselines for autorotations and landings
  - Abandoning predefined usage data
  - Clarification of EE360 compilation instructions
  - Optimisation of originally conceived DUS grouping for UM
- Some not seen through:
  - No access to OEM fatigue substantiation
  - No explicit endorsement sought from OEM regarding the adequacy of the Squirrel UMS
- Squirrel had evolved from only capturing airframe hours for the first 16 years of its life to categorically accounting for each DUS flight regime in the last seven years of its life with the ADF

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Squirrel usage monitoring case study

The importance of OEM support that the ADF lacked

- Provided we are confident that the request for information sent to the OEM and the response from the OEM are consistent, OEM advice and documentation (typically) gives us the highest level of confidence relating to our understanding of the level of safety inherent in our structural integrity systems (in this particular case, our UM system)

- As for Squirrel:

  - OEM advice was sought on numerous occasions over a number of years to investigate usage exceedances
    - But in hindsight, we did not necessarily ask all the right questions

  - OEM advice implicitly endorsed baselines to measure usage against and the UM groups that RWS section developed, however the endorsement was not explicit and was not followed up

Lessons identified (and learnt?)

- Strong appreciation, awareness and understanding of structural integrity within the helicopter community (i.e. PO, SPO, Operators, Maintainers) gives you the best chance to implement a mature program from day one and continue through life with a robust structural integrity management program

- Hence, the importance of a strong structural integrity SME community. We must continue to invest in SME:
  - We should continue to view such a capability as important, culturally
  - The Squirrel case study shows we need to invest more if anything, not less, to sustain SME capability:
  - Retention of corporate knowledge a problem
  - Depth of individuals with the right attributes:
    - critical thinking skills, ability to handle complexity, comms skills, etc

Lessons identified (and learnt?) (continued)

- **'But the goal posts are always changing!'**
  - They really aren't. This perception is more often a symptom of our knowledge/corporate knowledge being deficient
  - We tend to either misunderstand requirements or periodically relearn them

- **'But we've never had an accident due to critical part failure!'**
  - A surprisingly common argument from non-SMEs
  - An indefensible claim, and one never argued by SMEs
  - Reality: should never expect such events, even in a large international fleet size
  - Whilst it is difficult to demonstrate the accident you prevent; it is not a credible or defensible strategy to rely on passive fatigue management, and 'the safety inherent in design'
  - How much is enough?: Meet the requirement/SFARP (judgement)

Lessons identified (and learnt?)

- The importance of OEM support before contracts are drafted and the aircraft procurement is finalised
- The experience of Squirrel structural integrity management provides very useful insight for how we currently progress with:
  - MH-60R Romeo structural integrity management, an example where we are contractually in a position without OEM support
  - CH-47F Chinook Foxtrot structural integrity management where we have US Army and Boeing support
  - keep an open mind, seek to understand and ask questions, especially the big one - is your system as optimised as it can be?
  - Ensure you communicate risk to the appropriate Risk Management Authority

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Concluding remarks

- Regardless of what your Regulatory suite mandates, structural integrity management is vital
- Learnt a lot through lessons from squirrel SI program and other platforms, made good progress and have much improvement to come; stay tuned for:
  - ASIP Reviews for all other in-service helicopters
  - HUMS Policy under DASRs?
  - Regime Recognition for all ADF helicopters?

Thank you

QUESTIONS