

HELICOPTER VIBRATION – SHOCK AND VIBRATION QUALIFICATION OF EQUIPMENT

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SUMMARY

This webinar reviews the source of vibration loading on a helicopter and describes standard qualification tests that are used to ensure the safe life of equipment on the aircraft. It describes how the vibration environment can be measured in terms of a Fatigue Damage Spectrum (FDS) and Shock Response Spectrum (SRS). These spectra are calculated from measured flight load data as well as from the vibration test. By comparing the flight spectra with the test spectra, the paper shows how highly optimized vibration tests are derived. Although the paper deals specifically with helicopters, these techniques are now common in all industries, including: ground vehicles, offshore, power generation and electronics.

1: Introduction

All aircraft vibrate and all components are designed, tested and certified to survive these vibration levels over their entire service life. Helicopters are particularly challenging with regards to vibration, and this webinar describes the latest techniques for quantifying vibration-induced fatigue damage on components and structure.

One important technique derives tailored vibration tests directly from measured flight load data. Accelerometers record the vibration levels at a number of positions on the aircraft whilst it flies a prescribed sequence of manoeuvres. The fatigue damage dosage for each manoeuvre is calculated using a FDS (Fatigue Damage Spectrum), which effectively plots damage vs. frequency. The damage from each manoeuvre is summed over the usage profile of the aircraft to determine the whole-life damage dosage. From this profile we determine a statistically representative vibration test which contains at least the same damage content as the whole-life, but over a much shorter test period. 'Test Tailoring' in this fashion is now supported by several design standards, including: US Defence Standard MIL-STD-810F, RTCA DO-160E, and French Defence Standard GAM-EG-13.

The technique also offers a means of comparing damage severity across different vibration tests and different aircraft platforms. This enables us to use test and service evidence obtained on one aircraft platform to qualify equipment on a new platform. This 'read-across' evidence has been successfully used to qualify equipment without the need for any additional vibration testing. It offers considerable cost savings and supports the rapid deployment of mission-critical equipment.

2: Review of background theory – Fatigue Damage Spectrum (FDS) and Shock Response Spectrum (SRS)

The webinar starts with a review of the background theory.

The SRS is used to determine the maximum peak amplitude of loading which typically results from extreme shock events such as severe landings, impact, weapons discharge or nearby explosions. These extreme events can give rise to catastrophic failure as component stresses exceed the design strength. The SRS plots peak vibration amplitude vs. frequency.

The FDS is used to accumulate the damage caused by long term exposure to fatigue damaging vibrations which, although modest in amplitude, give rise to microscopic cracks that steadily propagate over time and lead to eventual fatigue failure. The FDS plots fatigue damage vs. frequency.

Figure 1: shows a comparison of both spectra for in-flight and test vibration levels. In this case the vibration test exceeds the in-flight damage accumulation by an acceptable safety margin.

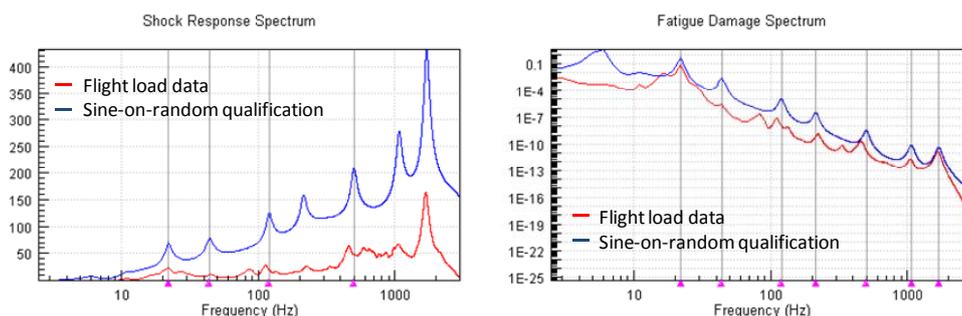


Figure 1: Comparison between shock and damage for in-flight and vibration test

3: Test Tailoring – Deriving an optimized vibration test

The objective of test tailoring is to derive a qualification test that contains at least the same fatigue damage content as the real aircraft

environment but in a much shorter test time. A shorter test will require greater vibration amplitudes in order to achieve the same degree of damage in a shorter period. The SRS is used to compare the worst amplitude seen in the test against the worst amplitude seen in-flight.

The worst shock loads are seen very rarely in-flight; whereas, the fatigue damaging loads are typically modest in amplitude but exist over very long periods. Test tailoring uses this effect to derive the optimum test duration. The optimum test duration is achieved when the SRS of the test coincides with the SRS of the worst flight condition. This allows the test to operate at it's most efficient where damage is accumulated at the maximum rate without exceeding the worst loads seen in flight. The analysis procedure is discussed in the webinar and illustrated in Figure 2:

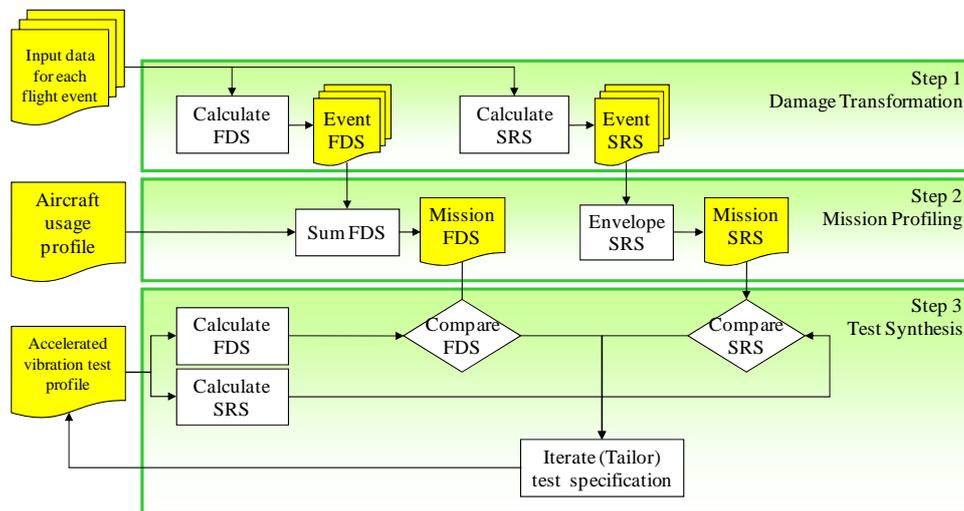


Figure 2: Test tailoring for helicopter qualification

4: Case Study 1 – Test tailoring for safety-critical control rods

New yaw control rods and mountings were required on a helicopter. These components are flight safety-critical so a test tailoring exercise was performed to assess the inherent safety margin. Figure 3: shows how the existing test underestimates the in-flight damage at the higher gear meshing frequencies. The tailored test offers a much better safety margin over the entire frequency range and is also more efficient and economic. The analysis is discussed in the webinar.

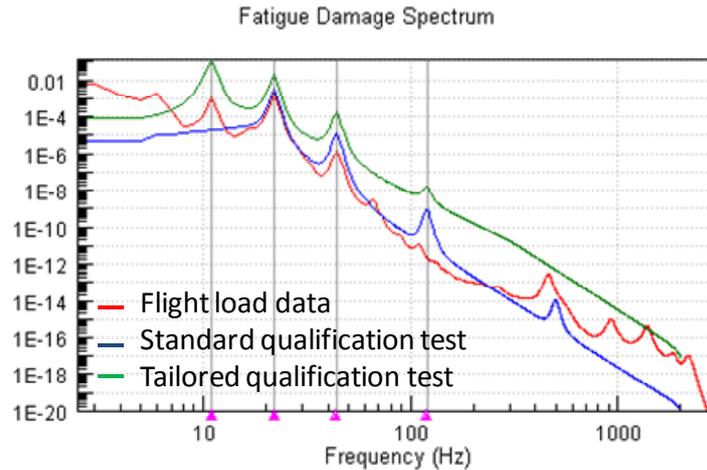


Figure 3: Damage comparison between in-flight, standard test, and tailored test

5: Case Study 2 – Vibration qualification from ‘read-across’ analysis

Equipment was urgently required for deployment on a military helicopter. No vibration qualification had been performed for this aircraft; however, previous clearance had been awarded for a different helicopter type. The objective of this analysis is to compare the damage content of the original aircraft test with that required for the new helicopter and assess whether the existing qualification evidence is sufficient for flight approval on the new helicopter.

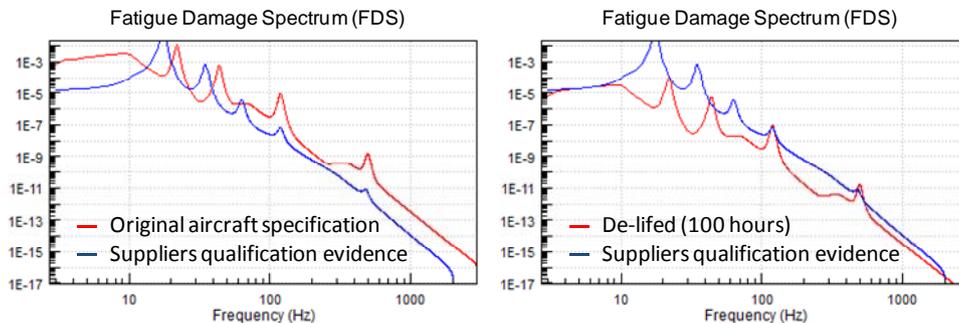


Figure 4: Damage comparison between current aircraft requirement and existing test evidence

From Figure 4:a, the existing qualification evidence underestimates the damage on the new aircraft over certain frequencies. However, by de-lifing the equipment from 10,000 hours to 100 hours, the equipment can be safely deployed. In this case the equipment was deployed urgently whilst further qualification tests were performed in order to extend the life. The analysis is discussed in the webinar.