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Vibration

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Vibration

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Vibration – Requirements & Guidance

- CS 27/29.251, each part of the rotorcraft must be free from **excessive vibration** under each appropriate speed and power condition.

- CS 27/29.571 Fatigue tolerance evaluation of metallic structure
  A fatigue tolerance evaluation of each Principal Structural Element (PSE).
- CS 27/29.573 Damage tolerance and fatigue evaluation of composite rotorcraft structures
- CS 27/29.613 (c) Strength…

- FAA AC 29-2C Chg 2 (25.04.2006) AC 29.251
  flight requirement may be both a qualitative and quantitative flight evaluation.
  - **Min-Max rpm, Speed VNE** (1.11 margin)
  - During the official FAA/AUTHORITY/TIA flight tests, critical parts of the rotorcraft may have limited instrumentation to reinvestigate and confirm that the critical conditions investigated during the flight load survey are satisfactory and do not result in **excessive vibration**

Vibrations – Requirements

→ CS 29.771 Pilot compartment

(c) The vibration and noise characteristics of cockpit appurtenances may not interfere with safe Operation.

→ CS 29.1321 Arrangement and visibility

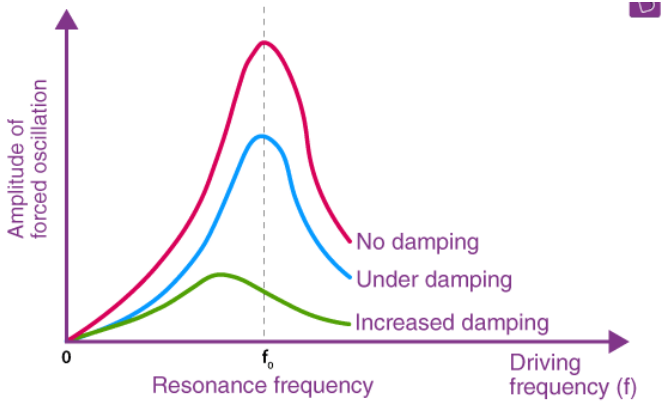
(f) Instrument panel vibration may not damage, or impair the readability or accuracy of, any instrument". In this case there is clear indication that vibration level has to be evaluated.

→ CS 29.1193 Cowling and engine compartment covering

(a): Each cowling and engine compartment covering must be constructed and supported so that it can resist the vibration, inertia and air loads to which it may be subjected in operation.

Vibration – Resonance

- Resonance is a phenomenon that occurs when an object or system is subjected to an external force or vibration that matches its natural frequency.
- When this happens, the object or system absorbs energy from the external force and starts vibrating with a larger amplitude.



➔ There is a risk of resonance on rotorcraft if the **natural frequencies** of an equipment / installation are found very close to the rotorcraft frequencies (main rotor, MGB, tail rotor, engine) with low **damping**

Vibrations – Objectives

→ Crew and occupants, and effects in handling qualities and controllability. Flight test panel responsibility.

→ Rotorcraft (airframe, rotor, drive system...)

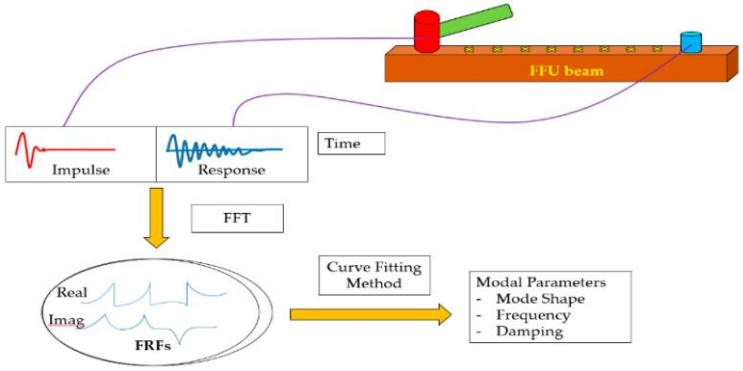
→ Systems and system Installation

  → System criticality & DO160 (see CS29.1301)

  → System installation (supporting structures, retention, MLP)

Vibrations – Compliance approach

- Vibration tests (ground or laboratory test)
- Flight test (AC 27/29.251 critical flight conditions & configuration)
- Alternatively, detailed design review / simulation and comparison with similar design (principle of AMC 27/29.307 Proof of Structure)



Vibrations – Compliance approaches

Identify the helicopter excitation frequencies (both **power on** and **power off** rotor speed ranges) [1/rev, 1n/rev, 2n/rev]

Variable NR

Multiple Variants

GROUND TESTING
(impulse hammer test)
Natural Frequency Determination

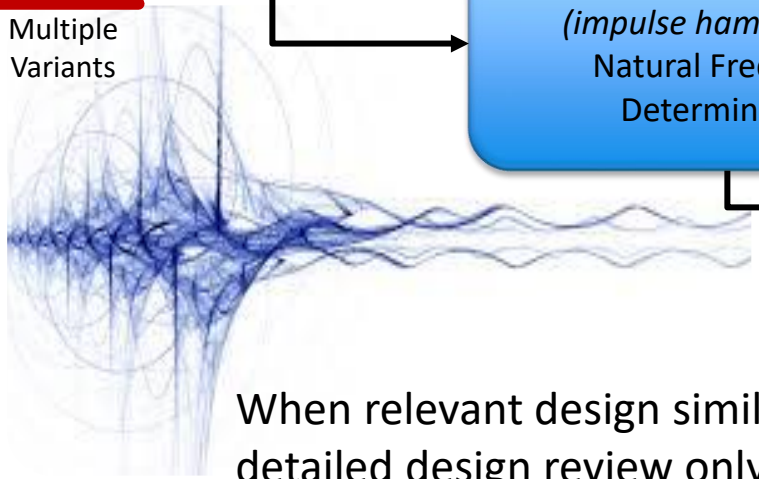
Design change

Compare with helicopter excitation frequencies

Instrumented FLIGHT TESTING as needed
1.11 Target VNE (POn & POff)
(Accelerometers)

Mitigate the risk of:

- Damaging systems and primary structure, including detachment,
- Detrimental effects in handling qualities and controllability,
- Detachment items of mass (within cabin/cockpit).



When relevant design similarity exists, detailed design review only may be accepted

Vibrations – Compliance approach

Main excitation sources

→ main rotor

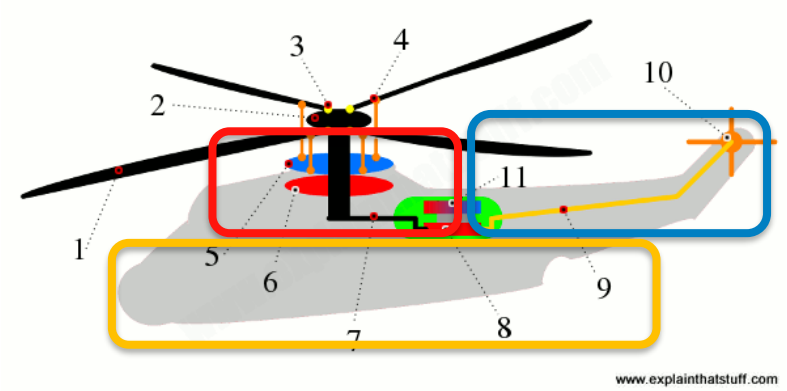
→ tail rotor

→ engine

→ Cooling fan

→ main rotor and tail rotor shafts

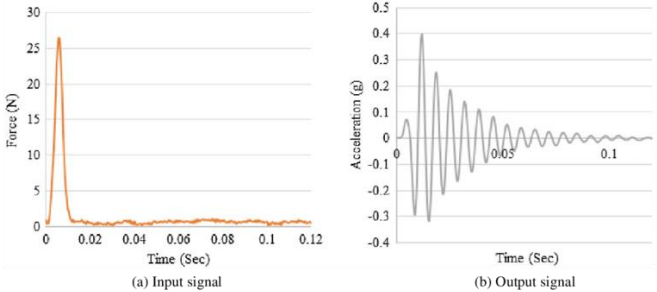
1/rev, 1n/rev, 2n/rev…



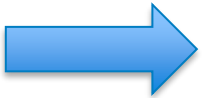
Excitation sources & Zonal

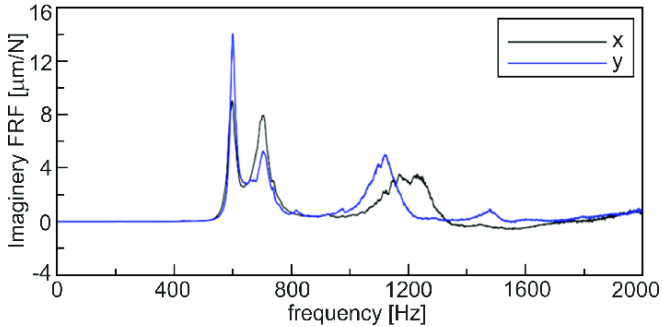
Vibration – Compliance approach – Impulse test

- The natural frequencies of new equipment / installation are measured through impulse test in all loading directions (Frequency Response Function)
- The measured frequencies are compared to rotorcraft Excitation frequencies:
  - If one or several of the installation/structures frequencies are within bandwidth of the rotorcraft excitation frequencies range (power on/off) , further investigation is needed.



(a) Input signal (b) Output signal





Frequency Response Function (FRF)

Vibration – Compliance approach - Flight test

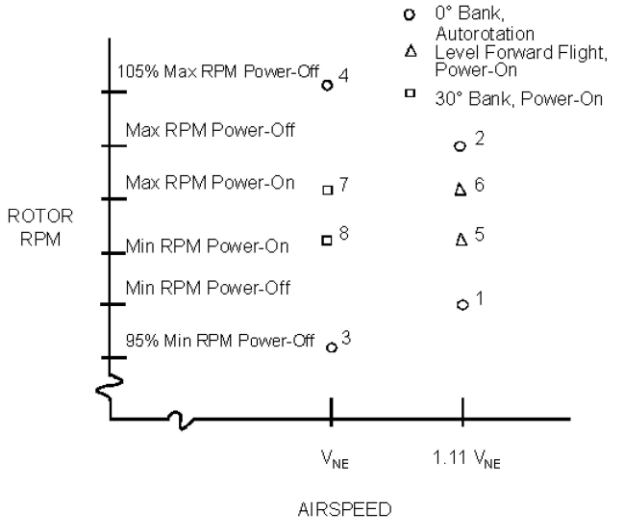
- For post-TC simple installations, flight test may be used instead of impulse test or may be necessary when resonance is identified.
- Vibration flight test is usually conducted together with other tests carried out to show compliance with other requirements (e.g. 27/29.143, 27/29.175, load survey)

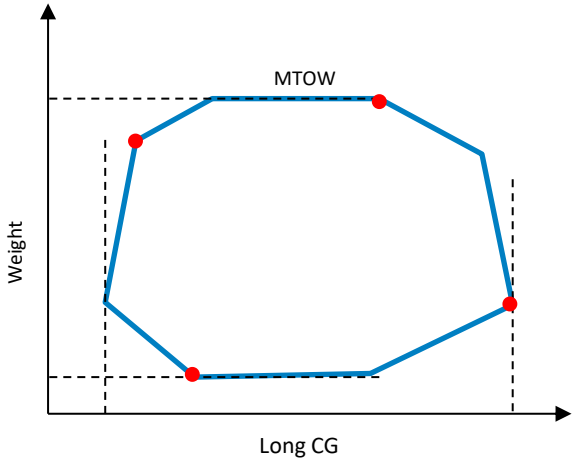
- Flight Test instrumentation
  - accelerometers installed on the helicopter and/or on equipment/installation
  - FTI Recorder
  - Time-history or (better) FFT shown on video for real time data monitoring

- AC 29.251 gives guidance for the flight test program
  - The conditions in fig AC 29.251-1 should be realized at least for the most critical condition of weight/CG, density altitude, and temperature

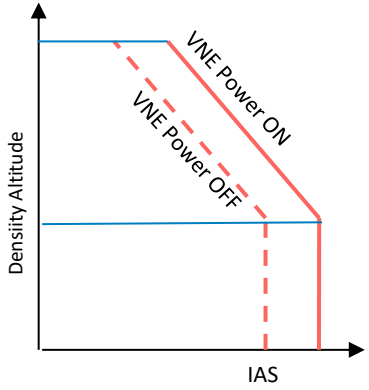
Vibration – Compliance approach - Flight test

- For a new TC/new model/basic configuration significantly changed
  - Various combination of Weight/CG at the altitude where highest VNE in EAS
  - Most critical test points repeated also at high altitude and at the minimum temperature



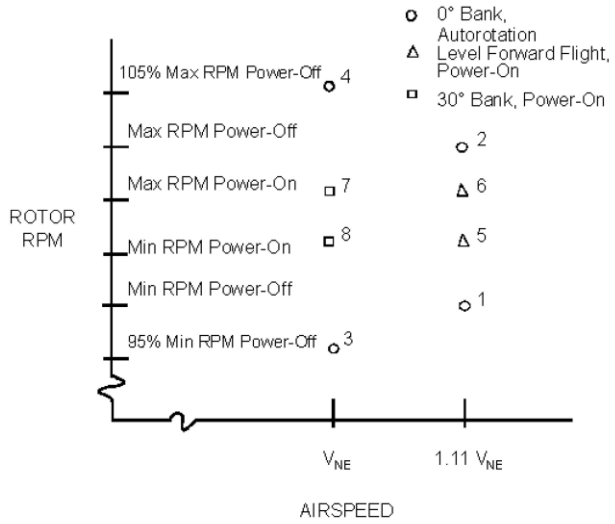


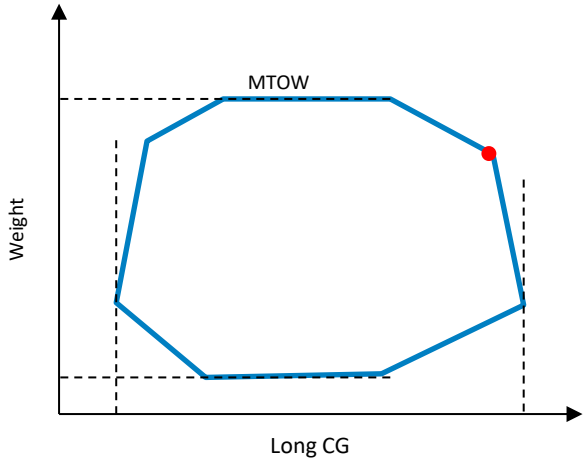
For certain configurations, the lateral CG should be also explored

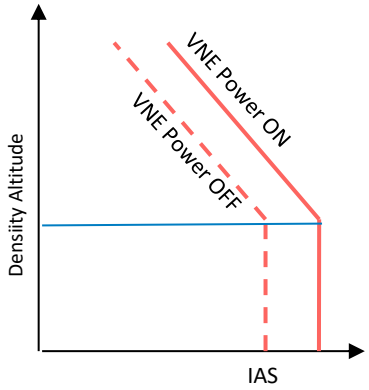


Vibration – Compliance approach - Flight test

- For a post-TC installation
  - The most critical condition of the basic aircraft (only 1 or 2 weight/CG @ 1 altitude)
  - The most critical configuration(s) of the system/installation







Vibration – Compliance approach - Flight test

- Evaluation of results
  - 27/29.251 and 571/613(c)
    - High levels of accelerations measured in flight on the equipment indicate low damping and/or presence of resonance.
    - The fatigue loads on installation / equipment are increased by the presence of resonance, and may need to be analysed for fatigue damage.
  - 27/29.771 and 1321
    - Pilot evaluation (also supported by measured data and/or video recording) for
      - readability of instruments
      - safe operation of controls
      - pilot fatigue and workload

Vibration – compliance approach – Analysis & Simulation

- Fem
  - To support test definition, configuration, conditions and similarity
  - Natural frequency determination for simple design/installation

Vibration – Conclusion

CS 27/29.251 vibrations must be addressed at Rotorcraft level and at structure/installation level

- Vibration identification by Impulse hammer testing and
- Flight tests as needed,
- In case of significant vibration, fatigue evaluation may be necessary.
- Alternatively, when relevant design similarity exists, detailed design review/simulation only may be acceptable (following the AMC1 27/29.307)
- Design Precaution (isolator, stiffness, MLP)

- Issue: quantify significant or excessive vibration (can’t be covered by DO-160 criteria)

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