PhD:

Comfort Aircraft Norms for Airlines Pax (CANAP)

1. CONTEXT

Long range aircraft customers are more and more demanding on cabin comfort vibration improvement. Current norms regarding comfort were defined for generic comfort from operating bulldozers to on-board trains (norm ISO 2631-1) or while on-board ships (Royal Navy Standard). But these norms are not pertinent to reflect comfort during commercial flights on civil aircraft.

When we try to apply current comfort norms on AIRBUS commercial aircraft, conclusion is green most of the time, even if crew or passengers complained.

As a consequence, comfort vibration understanding at Engineering takes a lot of time/energy and is not satisfactory vs. airlines and passenger complaints and expectations. Therefore an objective vibration comfort metric is needed. It will help in the development of new aircraft as a design target and can be used to demonstrate the vibration comfort of the AIRBUS fleet to our customers.

2. STATE OF THE ART

For the time being, the only available international norm in term of comfort is ISO 2631-1. In addition, the British Royal Navy developed their own standard but it is not recognized by the international vibration community. Both of these standards are not satisfactory when applied to our commercial aircraft, because:

1) the data reduction method to get to a vibration discomfort metrics is not adapted to commercial aircraft physical behavior nor to our aircraft sources of vibration;
2) the discomfort thresholds are not adapted to commercial aircraft environment.
3) Aircraft vibration discomfort is largely due to low frequency-large/displacement lateral motion, which is very specific and makes extrapolation of comfort metrics from other transportation industry (automotive, helicopters…) not relevant.

In addition, the current standards don't take into account "non vibration" factors such as air temperature and humidity, psycho-acoustics, passengers activities (reading, eating, drinking….) and passengers expectations. These human factors are a key in comfort assessment and make the difference between cars, helicopters and commercial aircraft.

In 2017, Airbus Helicopters, which has the same issue than Airbus Commercial Aircraft, launched a PhD on comfort based on vibrations. They will use our laboratory test mean to do the practical part of this PhD. The focus of Airbus Helicopters is different from our focus because:
- the vibration sources for helicopters are the rotors (strong level of multi-sine excitation) and the tail shake;
- the aircraft vibration comes from fuselage dynamic response to wind gusts / slats and flaps position (low level of broad band excitation from aerodynamics) and from aircraft engines fans (low level single sine excitation or beating).

From helicopters to aircraft, the physical phenomena (source of vibration) are different, the vibration levels are different, the frequency bandwidth is different. We are still in touch with the Airbus Helicopters PhD and we will use their results (bibliography, experimental protocol) but the methodology used to get vibration discomfort metrics from acceleration measurements is different for aircraft and for helicopters.

Some similar work was done in the domain of automotive industry, building architecture, trains but it is not usable neither for helicopters, nor for aircraft because the acceleration data reduction methodology is different.

CANAP PhD will be lead in collaboration with the acoustics and vibration laboratory of INSA Lyon which has knowledge and experience on comfort topics (they contributed to the definition of discomfort metrics for automotive industry) that we lack at Airbus. The PhD will be lead in the continuity of 10 years collaboration between AIRBUS commercial aircraft acoustics department and acoustics and vibration laboratory of INSA Lyon.

3. OBJECTIVE

CANAP project aims at customizing the ISO 2631-1 standard and adapting it to commercial aircraft flights in the frequency bandwidth [1; 100] Hz:

- Getting a method to calculate a comfort metrics from measured acceleration signals; this comfort metrics will be as representative as possible of the commercial aircraft passengers feeling.
- Getting a commercial aircraft comfort scale: perceptible threshold, unbearable threshold and gradual discomfort scale in-between.

In addition, the influence of some factors (not addressed in the ISO 2631-1 standard) will be studied to assess potential interaction with comfort vibration perception on board:

- Noise environment
- Visual environment
- Rotational acceleration (of axial or vertical axes).

The study will be oriented to get a comfort metrics easily usable on commercial aircraft, calculated as much as possible from the cabin floor acceleration measurements. At least, the variability linked with the seat transfer function will be quantified as a function of vibration frequency range.

The final objective is to be able to calculate a comfort value from on-board acceleration measurements and to compare this comfort value to a scale representative of commercial aircraft passengers comfort feeling for a given frequency bandwidth (1 to 100Hz). This will allow Airbus commercial aircraft to get a strong engineering judgement on comfort vibration topics relative to fuselage response to atmospheric turbulence (1 to 10Hz) and to cabin response to engine vibration (10 to 100Hz).

This work will be used to answer the airlines complaints about cabin discomfort. In the future, it can be used to propose an update of ISO 2631-1 standard for commercial aircraft flights.

4. WORK PLAN

For years, many flight tests data have been collected on Airbus flight test aircraft. Now with big data technology, we have developed a tool able to detect discomfort events and extract quickly from the flight test data lake the relevant information linked with passengers comfort feeling:

- measured acceleration signals along the cockpit and cabin
- flying conditions (Altitude, Mach number, speed slat/flap configuration, engines ratings)
- measurements needed for atmospheric turbulence assessment

The comfort data base built from flight test data is precious information but we need to connect it with passengers discomfort feeling (partial, unprecise or generally missing information during flight tests).

The PhD student will use the flight test comfort data base to build the vibration signals used for the laboratory tests with our 6 degrees-of-freedom vibration test bench. He will call for volunteers to attend vibration tests at our laboratory and collect people feedbacks. The results of the shaker tests will be used to get an objective human vibration discomfort metrics designed to become the Airbus Commercial Aircraft reference as a link between on-board acceleration measurements and people discomfort feeling during a flight. The tests will be performed as close as possible to real cabin environment (temperature, humidity, ambient noise and visual) to take into account human factors.

In the specific case of atmospheric turbulence issues, experiments will focus on the relationship between vibratory comfort and other kind of stimuli (audio and video ones). The interaction between all these information channels will be addressed, in order to know if a vibration metric can be useful on its own.

The main tasks of the PhD student will be to:

- Define a laboratory test methodology (experience plan);
- Call for volunteers and perform the tests at the laboratory in safety constraints;
- Sort and analyse the tests results

The final objectives of the laboratory tests are to:

- Define a data reduction methodology between acceleration measurements and people discomfort feeling, to get a vibration discomfort metrics;
- Correlate vibration measurements on-board during flight with people feelings and sensitivity thresholds;
- Identify people sensitivity thresholds vs. human factors (psycho-acoustics and people activities);
- Define objective criteria of comfort/discomfort for on-board civil aircraft.

Once these objectives achieved, the comfort metrics and sensitivity thresholds will be applied to the flight tests comfort data base to:

- Get a synthetic view of each aircraft family behaviour vs. comfort
- Try to compare our aircraft (one particular aircraft vs. the fleet, or one aircraft family vs. another one) and give our aircraft some comfort labels

- Improve comfort laws tuning and robustness, enabling the development of next generation of comfort laws

During this last phase, the PhD student will have to use gust estimation data from a methodology developed in the GUST project in collaboration with ONERA.

5. BIBLIOGRAPHY

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