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COMPARATIVE INTERIOR NOISE MEASUREMENTS IN A LARGE TRANSPORT AIRCRAFT – TURBOPROPS VS. TURBOFANS

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Abstract:
Aircraft cabin noise is an important factor that affects not only the passengers but also the pilots and aircraft crew. When comparing aviation to the other modes of transport, the shorter journey duration is of greater importance to the passengers than the noise pollution, but the noise still disturbs them a lot and can cause different health problems. Noise impact on pilots and cabin crew can be significant because it can reduce flight safety. Noise produced by large aircraft is much greater and more intensive than the one produced by the small ones. It has a broader frequency spectrum and it usually lasts longer.

The paper will try to compare the noise inside the cockpit in two large commercial aircraft, one being turboprop and the other turbofan. Furthermore, the comparison of cockpit noise during the various phases of flight, some simple statistical and octave band measurements will be conducted and a few possible methods of noise reduction will be discussed.

Key words: cockpit noise, turboprop, turbofan, noise reduction

1. INTRODUCTION

Internal noise was the major preoccupation of aircraft acoustic engineers for many years and still is important. Although, noise experienced on the ground has become a dominant factor in the acceptability of the airplane, in the late 1980's when prop-fans were being developed, internal noise become an important consideration too. Especially because it can cause different health problems of crew and passengers or disturb speech communication of pilots and so reduce the flight safety.

1.1. Effects of noise on people

There is a wide range of possible and known effects of noise on people. These effects are very subjective; two people exposed to exactly the same noise will experience slightly different negative effects. Thus, the problem of noise effects must be considered statistically in terms of the percentage of the population experiencing specific symptoms [1].

Damage on the hearing system is the most common consequence of noise exposure and it is usually described in terms of a shift in the threshold of sensitivity to low level sounds. Depending on duration and noise level threshold shift can be either temporary (TTS) or permanent (PTS). While the effects of noise on hearing are quite well understood, the effects of noise on other aspects of human physical and mental health are much less well understood. Psychiatric and cardiovascular diseases are just a few of the fields in which effects of noise exposure are observed.

2. CABIN NOISE SOURCES

Aircraft noise is generally divided into two sources: that due to the engines and that associated with the airframe itself. Structure borne noise as a particular kind of airframe noise is also interesting for observation. As higher bypass ratio engines have become more common and aircraft have become larger, interest in airframe-related noise has grown. Anyway, engine noise still accounts significantly in the overall internal noise which can be easy measured with the simple sound level meter.

Overall aircraft interior noise is combination of mentioned components that, with various degrees, penetrate into the aircraft cabin. The sources and paths of airborne and structure-borne noise resulting in interior noise in an airplane cabin are illustrated in Fig. 1 from [2]. Engine noise, in general, is highly dependent on propulsion type. The main types of aircraft engine are piston, turbojet, turbofan and turboprop but only the last two for needs of this paper will be observed more.

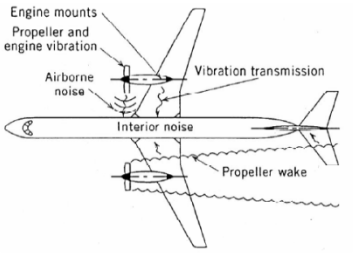

Fig.1. Sources and paths of airborne and structure-borne noise resulting in interior noise in an airplane cabin

2.1. Turbofan engine noise

High-bypass turbofans emit noise from two different sources: jet noise and fan loading noise. Jet noise is produced by a high-velocity jet exhausted from the core of the engine and a fan noise is the result of the pressure disturbance that must be resolved at the trailing edge of the blade. Unlike the low-bypass turbofan engines on older aircraft where both of these components dominate, the jet noise component of high-bypass turbofan engines is reduced, so that the fan loading noise dominates. Diagram of a high-bypass turbofan engine can be seen in Fig. 2.

Airbus A319 is a turbofan transport aircraft in which was done the interior measurement included in this paper.

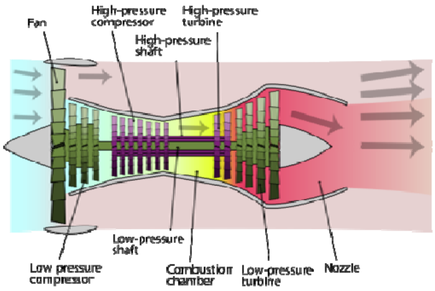

Fig. 2. Schematic diagram of a high-bypass turbofan engine

2.2. Turboprop engine noise

A turboprop consists of two main parts, the prop and the turbine engine; the prop moves air to create thrust and the turbine engine provides the power cycle (compression, combustion, energy extraction). Schematic diagram showing the operation of a turboprop engine can be seen in Fig. 3.

Turboprop noise is caused by periodic sources such as rotating engine parts, rotating props and by vortices shed from the propellers. Unlike jet noise spectrum which is dominated by high frequency broad band noise, turboprop noise spectrum is dominated by a few low frequency tones and such noise cannot be controlled by putting sound absorbing material in the walls of the fuselage [3].

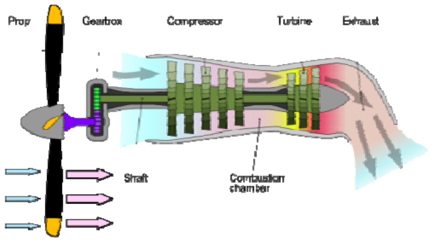

Fig. 3. Schematic diagram showing the operation of a turboprop engine

All Dash 8s delivered from the second quarter of 1996 (including all Series 400s) include the Active Noise and Vibration Suppression (ANVS) system designed to reduce cabin noise and vibration levels to nearly those of jet airliners. To emphasize their quietness, Bombardier renamed the Dash 8 models as the Q-Series turboprops. Dash 8Q-400 is a turboprop transport aircraft in which was done the interior measurement included in this paper.

3. THE BASIC AIRCRAFT DATA

The basic aircraft specifications can be compared in the table 1.

	Airbus 319	**Dash 8-Q400**
Cockpit crew	**2**	**2**
Seats	**132**	**76**
Wing span	**34.10 m**	**28.42 m**
Fuselage length	**33.84 m**	**32,83 m**
Wing area	**122.40 m2**	**63.08 m2**
Max T/O weight	**70000 kg**	**29257 kg**
Max cruising altitude	**11900 m**	**7620 m**
Max cruising speed	**834 km/h (450 kn)**	**667 km/h (360 kn)**
Engines	**2 x CFM 56**	**2 x Pratt & Whitney, PW 150A**

Table 1. Basic aircraft specifications

Figs 4 and 5 show aircraft which were used for interior noise measurements.

Fig. 4. Airbus A319-100

Fig. 5. Dash 8Q-400

4. THE EXPERIMENT

3.1. Measuring methods and equipment

Measurements of the cockpit noise were performed by locating the audiometer between the captain and copilot seats within the cockpit space (Fig. 6.), on the route Zagreb – Dubrovnik (Airbus A319) and Zagreb – Split (Dash 8Q-400).

Fig. 6. Locating the audiometar in the Dash 8Q-400 cockpit space

Since the certification and noise measurement is not standardizes, for the comparison reasons, the measurements were done in typical operating conditions or flight regimes:

1) at the apron, engines turned off, APU plugged in
2) taxing to runway
3) take off run
4) climb
5) cruise, recommended power
6) descend
7) descend in approach to landing, gear down
8) roll off.

Sound was recorded in time period of 30 seconds for each regime and finally some characteristic results are calculated, presented and discussed.

The noise was measured by means of Nor140 Sound Analyzer with an extensive set of functions available in its expanded version including level/time measurements, octave filters and statistics in every frequency band. The spectral weighting functions A- and C- or Z-weighting are available for all functions and the instrument functionality includes the ability to measure with all three time constants (F, S, I) applied simultaneously. The Instantaneous Sound Pressure Level (SPL), The Maximum Sound Pressure Level (Lmax), The Minimum Sound Pressure Level (Lmin), The Integrated Averaged SPL (Leq) and The Sound Exposure Level (LE or SEL) are some of the measured parameters discussed in this paper. Octave band measurements and some simple statistical parameters are also included. During the planning of the measuring set and the procedures, the applicable recommendations from ISO 5129 and AC 20-133 were used.

3.2. The results

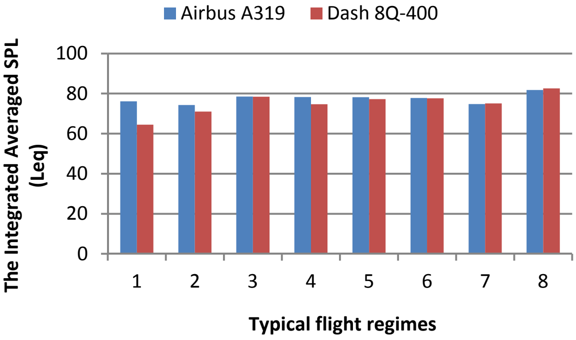

Fig. 7. Comparison of A-weighted Integrated Averaged SPL (Leq) for both aircraft in various operating conditions

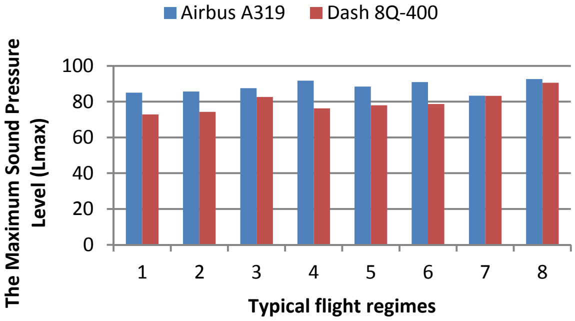

Fig. 8. Comparison of A-weighted Maximum Sound Pressure Level (Lmax) for both aircraft in various operating conditions

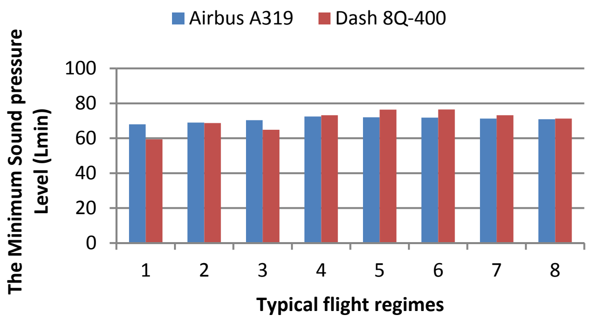

Fig. 9. Comparison of A-weighted Minimum Sound Pressure Level (Lmin) for both aircraft in various operating conditions

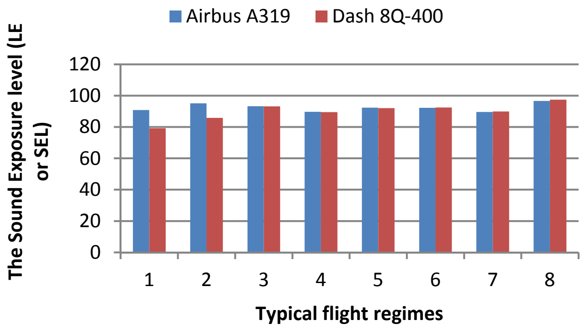

Fig. 10. Comparison of A-weighted Sound Exposure Level (LE or SEL) for both aircraft in various operating conditions

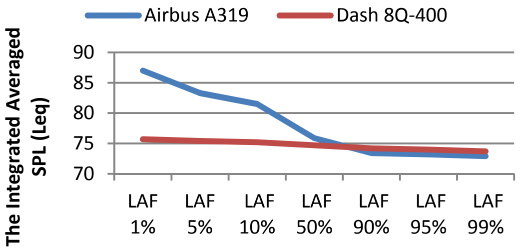

Fig. 11. Comparison of A-weighted Leq Percentiles for both aircraft in "climb" flight regime

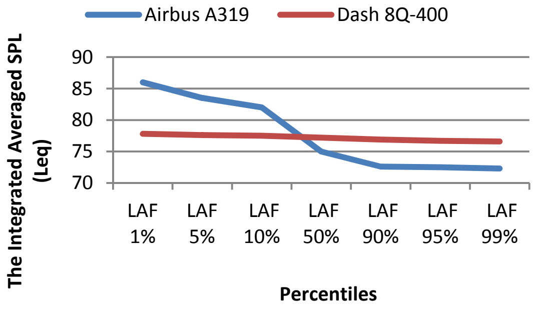

Fig. 12. Comparison of A-weighted Leq Percentiles for both aircraft in "cruise" flight regime

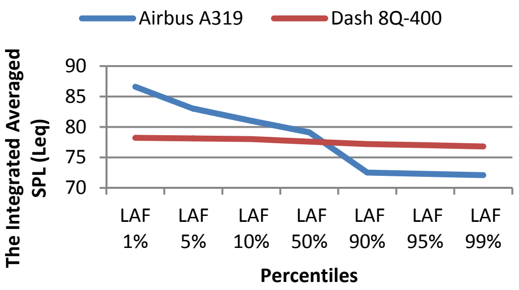

Fig. 13. Comparison of A-weighted Leq Percentiles for both aircraft in "descend" flight regime

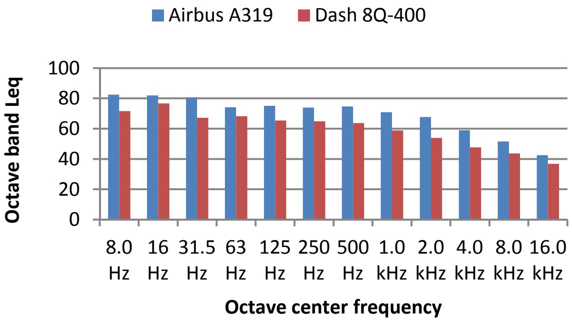

Fig. 14. Octave-band results in flight regime ‘1’

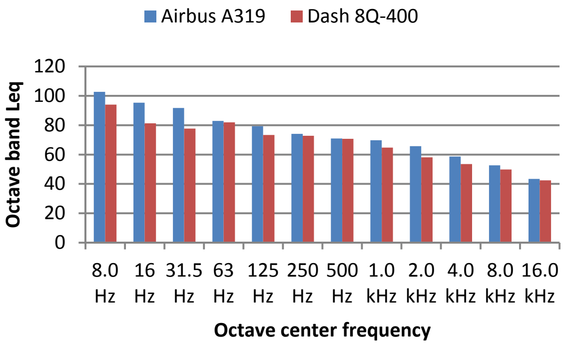

Fig. 15. Octave-band results in flight regime ‘2’

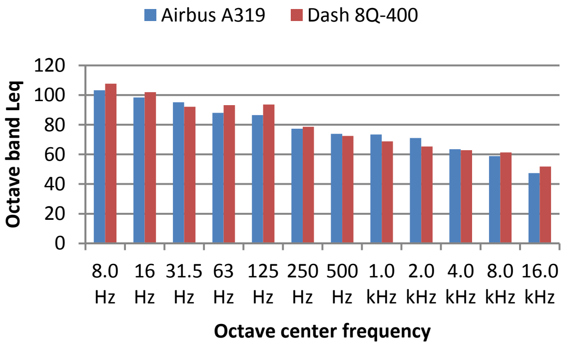

Fig. 16. Octave-band results in flight regime ‘3’

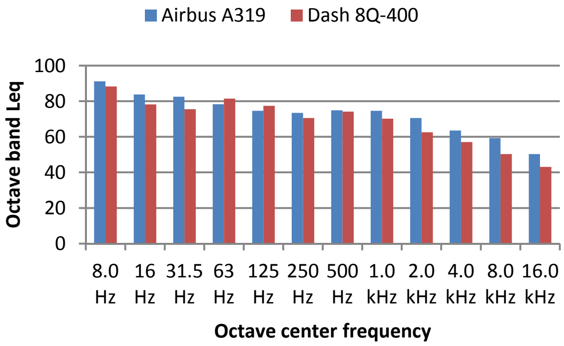

Fig. 17. Octave-band results in flight regime '4'

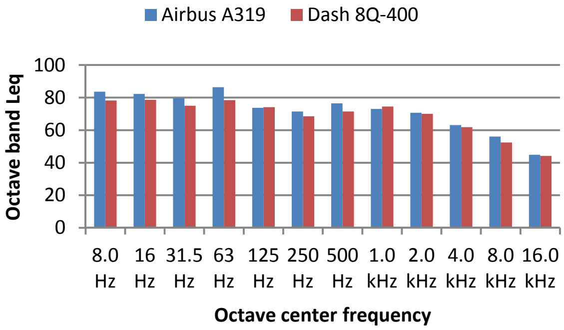

Fig. 18. Octave-band results in flight regime '5'

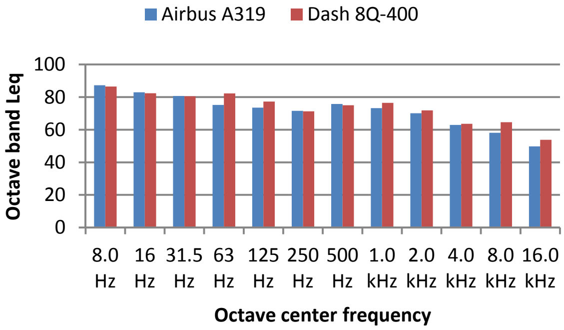

Fig. 19. Octave-band results in flight regime '6'

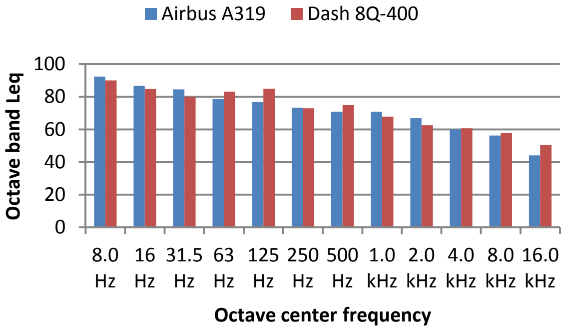

Fig. 20. Octave-band results in flight regime '7'

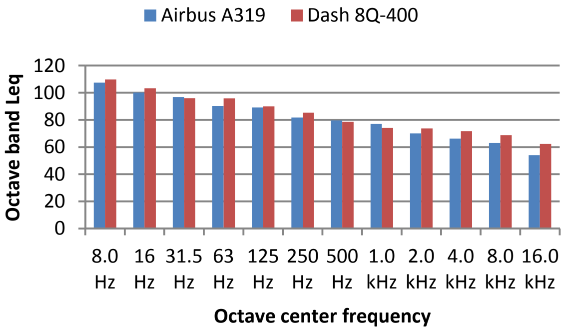

Fig. 21. Octave-band results in flight regime '8'

3.3. Discussion

Comparison of A-weighted Integrated Averaged SPL (Leq) for both aircraft in various operating conditions is shown in Fig. 7. The biggest difference in noise level is at the apron while engine are turned off and APU plugged in. About 11 dB greater noise is calculated in Airbus cockpit which can be described as significantly louder. Leq is greater or equal in all phases of flight except "roll off" where Dash noise is about 1 dB greater which can be described as just noticeable.

Comparison of A-weighted Maximum Sound Pressure Level (Lmax) for both aircraft in various operating conditions is shown in Fig. 8. Airbus Lmax is greater or equal in all phases of flight and the biggest difference is about 15 dB in "climb" regime. The smallest noise difference, 0,1 dB, is in descend in approach to landing while gear down.

Comparison of A-weighted Minimum Sound Pressure Level (Lmin) for both aircraft in various operating conditions is shown in Fig. 9. Airbus Lmin is greater in first three phases of flight while Dash Lmin is greater in last five observed phases of flight.

Comparison of A-weighted Sound Exposure Level (LE or SEL) for both aircraft in various operating conditions is presented in Fig. 10. Airbus cockpit SEL is greater for first two phases of flight with significant differences of about 10 dB. In next five observed phases of flight, there is no noticeable differences while Dash SEL is greater only in last observed flight regime.

Comparison of A-weighted Leq Percentile levels for both aircraft in three flight regimes of maximum duration are presented in Fig. 11., 12. and 13. Interesting to notice is that the level of 72 dB is exceeded for 95% of the measurement time for both aircraft.

Octave-band results in all observed flight regimes are shown in Fig. 14. - 21. Low frequency noise is dominated for both aircraft. Low frequency tones which exist in turboprop noise spectrum are most probably in 63 and 125 Hz octave center frequency band.

5. CONCLUSION

Unlike it was expected, cockpit noise is much greater in Airbus A319 than in Dash 8Q-400. Many aircraft companies and organizations like NASA constantly develop noise reduction methods. In considering aircraft noise generally, there is lot of space to reduce overall noise in aircraft interior. Putting the appropriate sound absorbing material in the walls of the fuselage is one of the simplest ways to gain in noise reduction. Some of engine noise reduction methods are very well known and are constantly developing by lots of different companies related to aircraft industry.

Interior noise can be also treated by placing the engines to minimize the noise directly radiated to the cabin, (e.g. using the wing as a shield) and by providing insulating material over the entire surface of the flight and passenger compartments. If the engines are mounted on the fuselage, vibration isolation is an important feature which must be observed too.

Although, the most of aircraft noise reduction studies are based on the noise reduction at the airports and airport vicinity, special attention should be also given to reduction of aircraft interior noise. Particularly, because it can impact on pilots and cabin crew and can be significant factor in reducing of flight safety.

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