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Noise Analysis of a Twin Piston Engine Aircraft

Jurica IVOŠEVIĆ[a], Ivan MIHALINČIĆ[a] and Tino BUCAK[a]

[a] Faculty of Transportation and Traffic Sciences, Department of Aeronautics,
University of Zagreb, Vukelićeva 4, 10000 Zagreb, HRVATSKA,
e-mail: jurica.ivosevic@fpz.hr,
icomihalin@gmail.com,
tino.bucak@fpz.hr

ABSTRACT

In aviation; the airports and the airline industry, a great number of people is exposed to high intensity noise. External aircraft noise, which is precisely defined and standardized through international regulations, adversely affects the ground crew while internal (cabin) aircraft noise significantly affects communication and comfort of the crew and passengers.

A number of internal and external noise measurements have been undertaken on two G/A twin piston engine aircraft, Piper PA-44 Seminole and Piper PA-34 Seneca III, and some of the results are presented and discussed, along with few possible methods of noise reduction.

1. INTRODUCTION

The highest allowed values of the external noise created by the aircraft are precisely defined in certification regulations by the ICAO standards and recommended practices and JAA requirements. Brand new aircraft can't become operational unless the above mentioned standards are met. Unfortunately, aside from the well-defined exterior (community) noise parameters and acceptable levels, neither of those standards deals with the interior (cabin) noise. Unlike the exterior noise, the interior or cabin noise disturbs only the users of the transport vehicle and is not precisely defined by the certification regulations.

Cabin noise and vibrations are certainly one of the most important factors that influence the comfort of passengers and crew onboard aircraft. Generally, the cabin noise level has to be sufficiently low not to disturb the acceptable level of comfort, and the noise range should be such that it allows satisfactory speech communication [1].

The characteristic and the level of noise depend on the aircraft type and the respective flight phase, which influences greatly the methods and procedures in controlling and reducing the interior noise. For instance, noise generated by the engines at full power during takeoff and the operation of thrust reversers in landing is much greater than the noise generated during cruising, although landing and takeoff are of relatively short duration so that the discomfort caused by exposure to higher levels of noise in those cases is considered acceptable. Since cruising takes the longest, special attention is paid to the control of interior noise for stationary conditions of comfort, especially for flights longer than 12 hours.

If we talk about the training aircraft cabin noise represents an important factor because it significantly influences the quality of speech communication between the instructor and the student - pilot [2]. Training aircraft make a large number of operations in one day and are distinguished from transport aircraft by a large number of takeoffs and landings. Since the noise is much higher during such operation regimes than during the cruising, it can result in fatigue of the instructor and the student alike thus endanger the safety.

In this paper the results are shown of the cabin noise measurements in the twin piston engine training aircraft Piper PA-44 Seminole and Piper PA-34 Seneca III. The noise measurements were conducted in typical flight regimes.

Piper Seminole, often used in flight training organisation fleets, is a typical representative of a twin-engine training aircraft and as such has been selected for measuring the noise. For comparison are shown the noise measurement results of a Piper Seneca which is in view of the characteristics and performance very similar to Piper Seminole. An important factor that significantly contributes to the overall noise spectrum is the difference in the number of blade.

Generally, different flight times, different regimes i.e. flight phases, as well as different aircraft types impose also different requirements regarding interior noise control. The best and the most practical way to reduce the noise inside the aircraft, and in that way to protect pilots and passengers from noise harmful effects, is the use of appropriate absorptive materials in the acoustic insulation of aircraft interior parts such as seats, doors, floor and ceiling. In addition, headphones do not contribute to the reduction of the overall level of cabin noise, but significantly contribute to human protection from that harmful aircraft emission [1].

2. AIRCRAFT CABIN NOISE SOURCES

Aircraft cabin noise is produced by various sources, being primarily the result of a combination of the turbulence in the boundary layer on the external cabin fuselage and the noise of the power plant sent directly through the air or by vibrations through the aircraft structure.

Noise is generated by sources such as intake and exhaust systems of piston and jet engines, propellers, turbulent airflow on aerofoils, fan/compressor and turbine of jet engines, etc. Fuselage transfers this noise along several transmission paths into the interior which contributes to the noise inside the aircraft. Thus airborne noise is distinguished from the structure-borne noise that is generated by the vibrations caused e.g. by the operation of the insufficiently balanced elements of the power plants [1].
However, within the aircraft fuselage, especially the large ones, there are significant noise sources as well which should also be taken into account.
In light propeller aircraft the best acoustic conditions can be found in front of the propeller rotation plane, deteriorating suddenly in the plane itself, and improving again towards the rear end. Therefore, the worst situation is in small two-engine propeller aircraft, since the propeller rotation planes are usually at the level of the cabin [2]. This is the case in our example.

3. BASIC AIRCRAFT DATA

Piper PA-44 Seminole
Equipped with two engines type Lycoming O-360 and propellers type Hartzell HC-C2Y(K,R)-2 CLEUF, it is mostly used for pilot training. Engines are air cooled, direct-driven, horizontally opposed 4 cylinder, rated at 180 hp (135 kW) at sea level; Propellers: 2-bladed, constant speed, fully feathering with pitch controlled by oil/nitrogen pressure. The aircraft capacity is four persons, maximum takeoff mass is 1723 kg, maximum speed is 374 km/h, and absolute ceiling is 5213 m.

Figure 1. Piper PA-44 Seminole and Piper PA-34 Seneca III

Piper PA-34 Seneca III
The Piper PA-34 Seneca is twin-engined light aircraft primarily used for personal and business flying. Continental TSIO-360-KB engines produced 220 horsepower (165 kW), although only rated as such for 5 minutes and then dropping to 200 hp (150 kW). The aircraft's gross weight is 4,570 lb (2,073 kg) for takeoff and 4,513 lb (2,047 kg) for landing. Powerplant: 2× Continental TSIO-360- KB cylinder, air-cooled, horizontally-opposed piston engine. The aircraft has 3-bladed propellers and its capacity is five or six persons.

4. THE EXPERIMENT

Measuring Methods and Equipment

Due to the complexity of acoustic measurements, for subjective determination of the cabin noise characteristics *in situ* the more detailed analysis is usually avoided and mostly three simple parameters are used: unweighted Overall Sound Pressure Level (OASPL), A-weighted sound pressure level and octave band level measurements.

Although the discussion is still going on about the most proper method of measuring cabin noise in order to assess the degree of speech interference, due to the simplicity the most commonly used is the A-weighted curve (International standard ISO 5129 also specifies octave-band or 1/3 octave-band SPL measurements though). For example, the levels of up to 70 dBA are considered good for the acoustic conditions in the cabin, whereas the levels above 90 dBA are definitely unacceptable. In the majority of today's commercial aircraft the level of cabin noise is generally lower than 80 dBA, so that the speech communication is mainly undisturbed. However, in smaller propeller piston engine aircraft the levels are considerably higher. Since the certification and noise measurement is not standardizes, for the comparison reasons, the typical operating conditions were selected:

1) idle, with no progressive speed;
2) cruise (i.e. 220 km/h);
3) maximum power, take-off conditions.

The noise was measured by means of Brüel & Kjær 2231 Sound Level Meter with octave filters. During the planning of the measuring set and the procedures, the applicable recommendations from ISO 5129 and AC 20-133 were used. Measurements of the cabin noise were performed by locating the audiometer between the front seats within the cabin space.

The Results

The wideband, A-weighted and octave-band measurements of the aircraft cabin noise were performed on the runway (idle and cruise conditions) for both of aircraft. Especially for the Seminole, A-weighted cabin noise measurements were performed in various operating conditions during the flight which is presented in Figure 2.

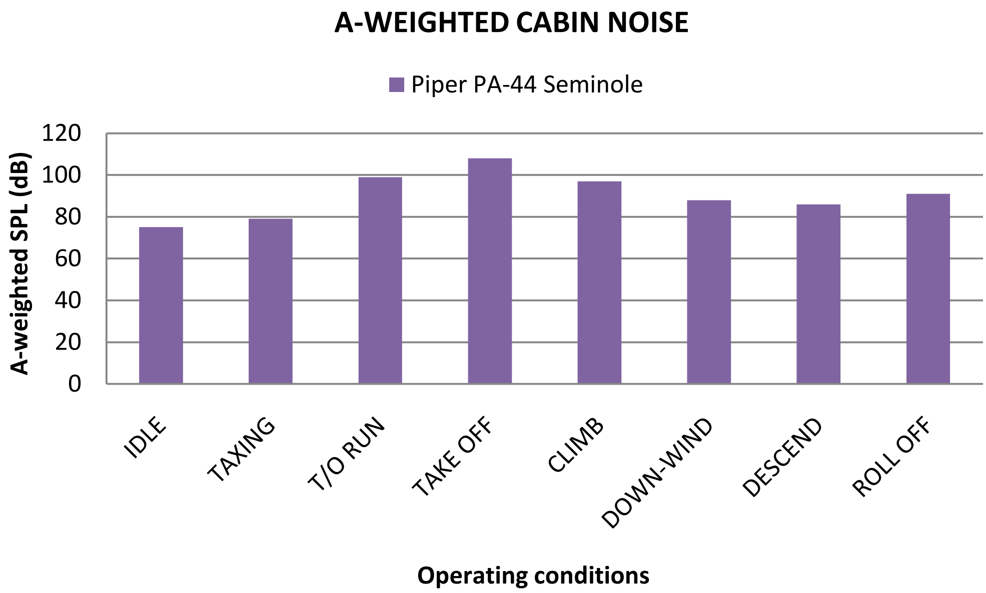

Figure 2. A-weighted cabin noise in various operating conditions

The results of measuring A-weighted cabin noise on the both aircraft for the three different operating conditions are presented in Fig. 3. and the results of octave measurements from 31.5 Hz to 16 kHz are presented in Figures 4 and 5.
Furthermore, especially at maximum take off power, A-weighted measurements were done for both of aircraft on the runway. At the time of measurements, there was no significant background noise interference.

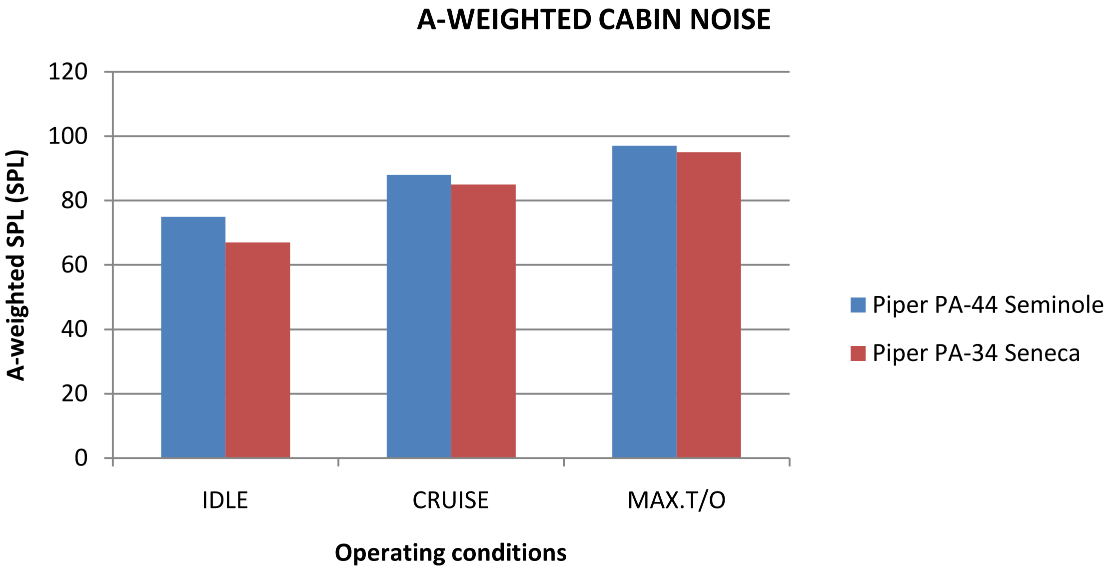

Figure 3. Comparison of A-weighted cabin noise for both aircraft in various operating conditions

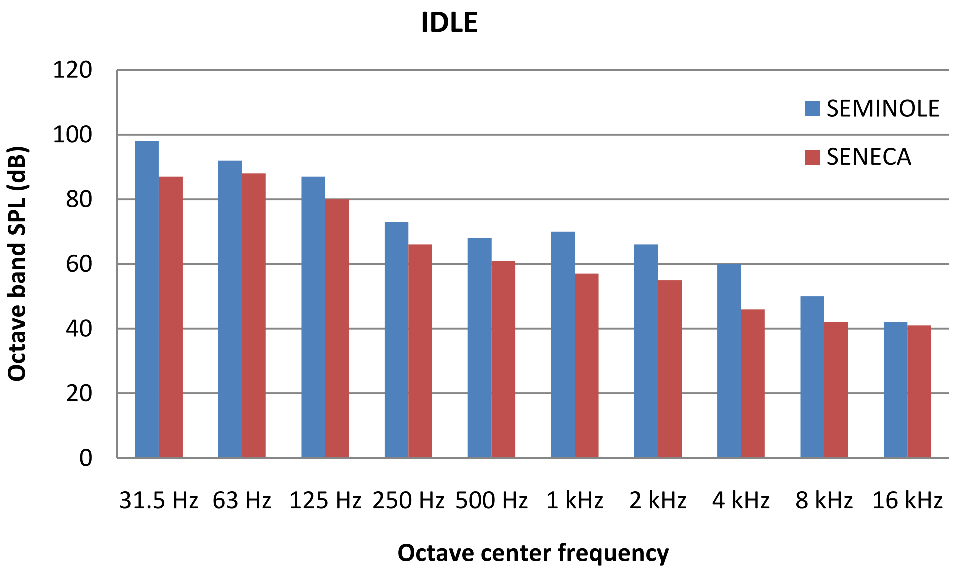

Figure 4. Octave-band results in idle operation

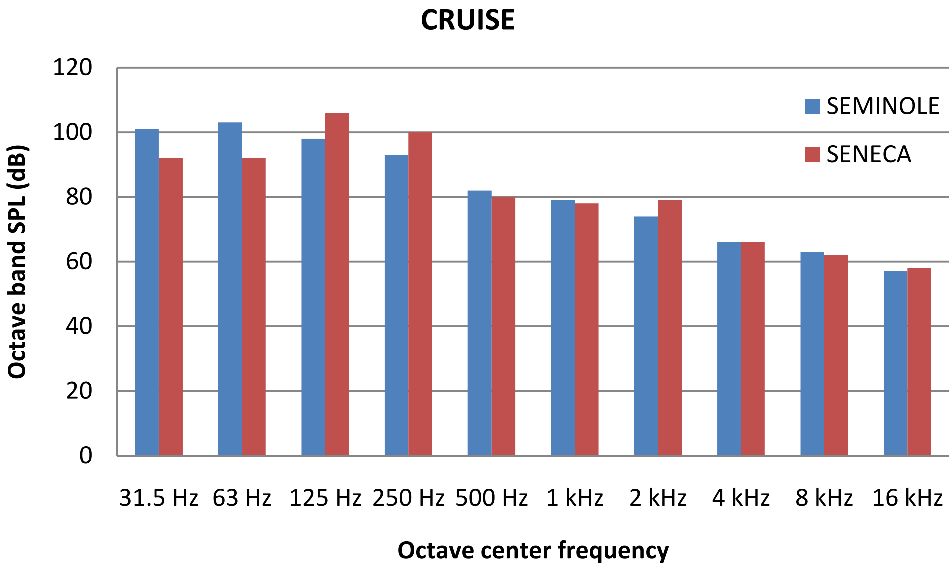

Figure 5. Octave-band results in cruise operation

5. CONCLUSION

The results of A-weighted cabin noise measurements in various operating conditions during the flight (Fig. 2.) show that the greatest noise is, like expected, at maximum take off power, 108 dB. That is quite unpleasant, but mitigating circumstance is of a short duration. Minimum noise is at idle and it amounts 75 dB what is relatively high, but still acceptable.
The results given by octave-band measuring of the cabin noise in idle show a difference of minimum 1 dB on 16 kHz to maximum 14 dB on 4 kHz between the aircraft, as in Fig. 4. In cruise a difference between the aircraft is minimum 1 dB on 16 kHz and maximum 14 dB on 4 kHz, as in Fig. 5.
The A-weighted results give a more realistic „psychological“ sound picture and the difference in idle is 8 dB, in cruise 3 dB and at maximum take off power it is 2 dB, as in Fig. 3.
The comparison of the results shows significantly higher noise levels in Seminole cabin compared to Seneca cabin, among the rest due to better performance acoustic insulation inside the cabin.
Today's piston engines for light aircraft have higher levels of noise because they are cooled by air and have poor exhaust silencers (mufflers). To introduce liquid-cooled engines and retrofit more efficient mufflers without deteriorating the engine performance could be a way to improve overall noise performance.

REFERENCES

[1] Bazijanac, E., Domitrović, A., Franjković, D.: Cabin Noise Comparison Between a Twin Piston Engine Training Aircraft and a Car, 3rd Congress of the Alps Adria Acoustics Association, Graz, Austria, 2007.
[2] Mixson, J. S., Wilby, J. F.: Interior Noise, *Aeroacoustics of Flight Vehicles, Vol 2: Noise Control*, Hubbard, H. H., ed., Acoust. Soc. Am., 1995.
[3] Bucak, T., Bazijanac, E., Domitrović, H.: Comparative Cabin Noise Analysis in Light Aircraft and Cars, 11th International Meeting on Low Frequency Noise and Vibration and its Control, Maastrict, The Netherlands, 2004.