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LIGHT TWIN PISTON ENGINE AIRCRAFT NOISE ANALYSIS IN AN UNUSUAL ATTITUDE FLIGHT

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Abstract:
High levels of interior noise are commonly inherent to General Aviation aircraft. Two dominant sources of noise of a small piston engine aircraft are power plant (propeller and engine) and aerodynamics (airflow around the fuselage), which by air and through the structure penetrates the aircraft and generates field of annoying sound – interior or cabin noise. This study investigates interior noise of a light twin piston engine aircraft Piper PA-44 Seminole in non-standard aircraft attitude, also known as unusual attitude – or upset – flight (traverse, slip, asymmetric flight and slow flight with high angle of attack). The data collected, analyzed and presented in this paper show significant noise change in both the levels and spectra generally due to asymmetrical loading of the propeller blades during unusual attitude flight, compared to attitude in regular cruising flight.

Key words: aircraft, interior noise, unusual attitude flight, propeller loading noise

1. INTRODUCTION

Noise is an unwanted sound which has certain intensity, is distinguished from other sounds and which is loud enough to be heard.
The characteristic and the level of aircraft cabin noise depend on the aircraft type and the respective flight phase. High levels of noise adversely influence concentration, communication and ability to effectively perform cognitive tasks [1]. 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 [2].
This study investigates interior noise of a light twin piston engine aircraft Piper PA-44 Seminole in non-standard aircraft attitude, also known as unusual attitude – or upset – flight (traverse, slip, asymmetric flight and slow flight with high angle of attack). This flight "scenarios" are well presented with its own sound spectra characteristics and levels. Before presenting and discussing the cabin noise measurements results in an unusual attitude flight, noise sources in small training aircraft and basic data of the aircraft that we used for the measurements will be shortly outlined.

2. CABIN NOISE SOURCES OF A SMALL TRAINING AIRCRAFT

Small training aircraft cabin noise is mainly generated by the power plant composed of engine and propeller and to some extent by aerodynamic airflow that affects turbulent boundary layer and external structure.
Engine noise is generated by internal combustion process. It occurs due to sudden changes in pressure within the cylinder and the interaction of cold air and hot exhaust gases.
Propeller noise is generated by spinning propeller and the airflow that streams around the blades. The nature of noise is mainly function of rotating frequency, number of propeller blades and physical characteristics of the blades, as well as the relative angle of the airstream inflow to the propeller rotating plane. The latter is the focus of our research in this paper.
Aerodynamic noise is caused by the airflow along the fuselage.
The above mentioned noise sources are also the main cabin noise sources. Their resultant vibration energy transmits to the aircraft structure and then reradiate into the cabin [3]. 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 twin-engine propeller aircraft, since the propeller rotation planes are usually at the cabin level [4].

3. THE EXPERIMENT

3.1. Piper Seminole PA-44 180

The Piper Seminole is a low wing, four place, all-metal, unpressurized, twin engine reciprocating aircraft equipped with retractable tricycle landing gear, considered to be the most utilized multi-engine training aircraft today. Some important engine and propeller data are presented as follows:

- Engines: Lycoming, O-360-E1A6D; LO-360-E1A6D, four cylinder, direct drive, horizontally opposed, air cooled;
- Rated horsepower: 180 hp at sea level;
- Rated speed: 2700 rpm;
- Propeller: 2 blades, constant speed, hydraulically actuated, full feathering.

Piper Seminole PA-44 180, 9A-DZG shown in Figure 1, used in the experiment is owned and operated by The Croatian Aviation Training Center at The Faculty of Transport and Traffic sciences.

Fig.1. Piper Seminole PA-44 180, 9A-DZG

3.2. Measuring methods and equipment

Interior noise measurements were performed in flight by Class 1 Sound Level Meter within the aircraft in typical non-standard aircraft attitudes: slip, traverse, asymmetric flight and slow flight and compared afterwards to the results gained in "standard" cruising regime.
During the planning of the measuring set and the procedures, the applicable recommendations from ISO 5129 and AC 20-133 were used.

3.3. The results and the discussion

3.3.1. Slip
The data gained during right and left slip, measured with octave band filter, and compared to cruising regime are presented in Figure 2. The results show changes in both spectra and levels of interior noise during the slip due to following: application of rudder and control yoke, change of airspeed and loss of altitude (300 ft) – due to increased aerodynamic drag, and change of power settings. The most significant change is in the low frequency band, up to 125 Hz, caused by turbulent airflow over the rudder and ailerons as well as the whole structure of aircraft. Above all and most important - since the aircraft was banking the airflow on both propellers became asymmetric, so the propellers became unevenly loaded compared to cruising regime.

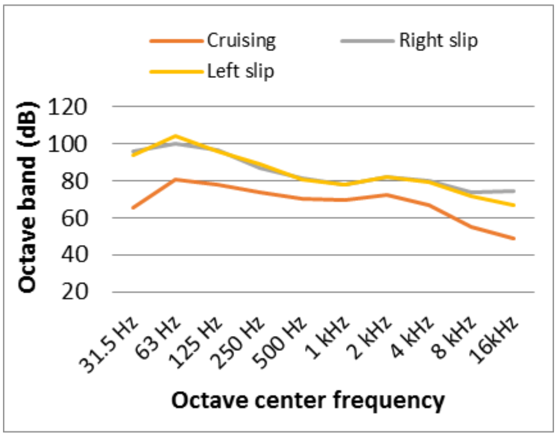

Fig.2. Interior noise levels in slip and cruising regime, octave band filter

Figure 3 shows data gained with A-weighting in slip and cruising regime. This graph shows a sound image which can be described as more subjective to humans than one presented with octave band filter. Measured noise level in right slip was 88,4 dBA, in left slip 88,6 dBA and in cruising regime 76,9 dBA.

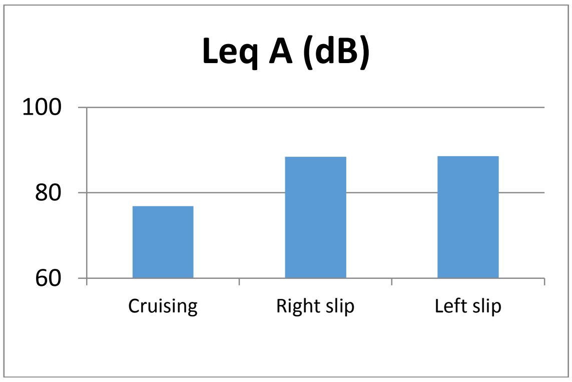

Fig.3. Equivalent Sound level in slip and cruising, A-weighting

3.3.2. Traverse
During the traverse measured noise level is even higher than during the slip. In order to perform the traverse it is necessary to apply only the rudder, but considering that there were four persons inside the aircraft, the power setting was increased for safety reasons, what automatically increased the noise level compared both to slip and cruising regime, mostly in low frequency band. It can be concluded that aerodynamic noise is a less

important factor in the whole sound image than the power plant noise. Figures 4 shows comparison of interior noise in traverse and cruising regime, measured with octave band filter.

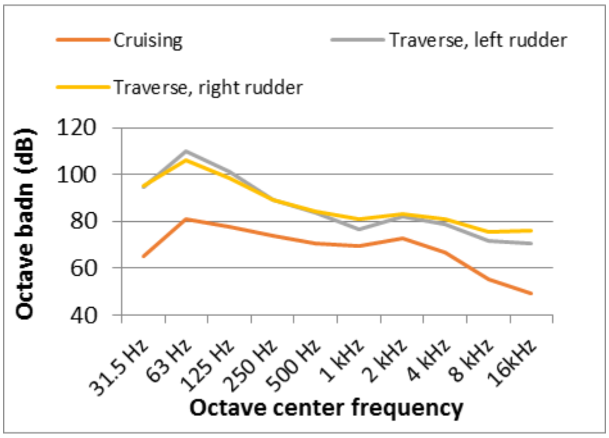

Fig.4. Interior noise levels in traverse and cruising regime, octave band filter

Figure 6 shows data gained with A-weighting in traverse and cruising regime. Measured noise level in traverse with left rudder was 90,9 dBA, in traverse with right rudder was 90,5 dBA and in cruising regime 76,9 dBA.

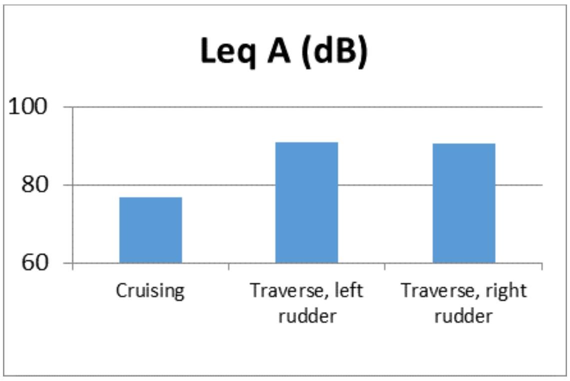

Fig.5. Equivalent Sound level in traverse and cruising, A-weighting

3.3.3. Asymmetric flight

The analysis of data gained while the both engines, intermittently, where on idle, in the first measurement without rudder application and in second with rudder application, show in all cases increase of noise level compared to cruising regime. While one engine is in idle position, the airspeed reduces and the propeller is in the position for high RPM. With rudder application the noise level changes just noticeably, what reaffirms the conclusion that the power plant is dominant source of noise on this type of aircraft. The overall noise level is higher than in cruising regime because of irregular airflow over the control surfaces, and considerably because of change of airflow's angle of incidence to the propellers of both engines. Comparison of asymmetric flight and cruising regime, measured with octave band filter, is shown in figure 6.

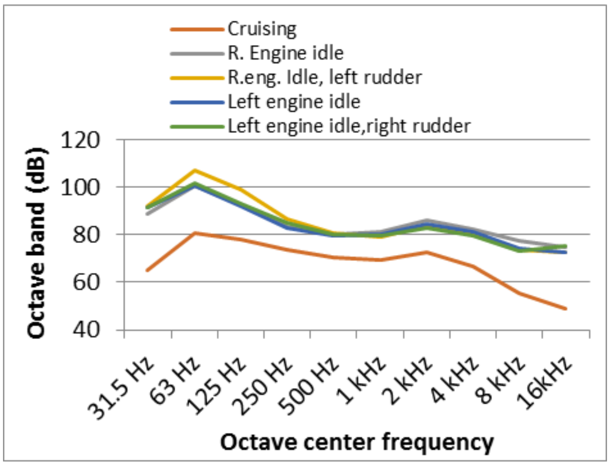

Fig.6. Interior noise levels in asymmetric flight and cruising regime, octave band filter

Figure 7 shows data gained with A-weighting in asymmetric flight and cruising regime. Measured noise level when right engine was in idle without rudder was 90,3 dBA; with left rudder 90,3 dBA; for left engine in idle was 89,2 dBA, with right rudder 88,5 dBA, and in cruising regime 76,9 dBA.

It can be noticed that there is a little difference between noise level with and without application of rudder, what again indicates that noise produced by airflow over control surfaces (aerodynamic noise) is a minor factor in overall sound image.

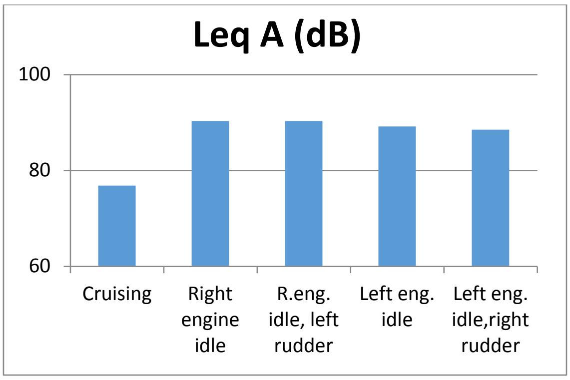

Fig.7. Equivalent Sound level in asymmetric flight and cruising, A-weighting

3.3.4. Slow flight

Slow flight in Piper PA-44 Seminole can be performed, due to safety reasons, with maximum two persons on board. Considering that during these measurements were four persons on board, it wasn't possible to perform the conventional slow flight, but slightly modified the way that is illustrated in Figures 9 and 10. In the first measurement, "slow flight", airspeed was reduced to 80 kn and maintained, the power setting was reduced to 1500 RPM, and the altitude was 3000 ft. With the first nose lowering, to angle of attack of -2°, airspeed increased to 81 kn, loss of altitude was 250 ft. With even lower angle of attack, -4°, airspeed increased to 85 kn, and loss of altitude was overall from 3000 ft to 2620 ft. In the last case, with propellers in high RPM position, airspeed was 80 kn and altitude was 2450 ft.

Increase in noise level during slow flight, especially in low frequency band, is due to high angle of attack what increases overall turbulent airflow over the structure of aircraft, and causes the change of airflow's angle of incidence into the propellers, increasing propeller loading. Data gained in slow flight and compared to cruising regime, measured with octave band filter, are shown in figure 8.

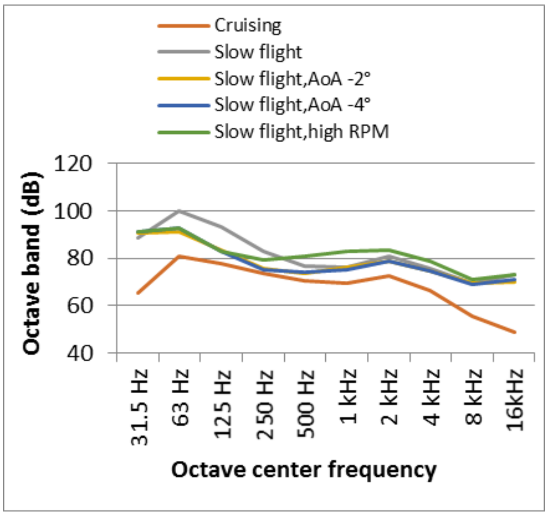

Fig.8. Interior noise levels in slow flight and cruising regime, octave band filter

Figure 9 shows data gained with A-weighting in slow flight and cruising regime. Measured noise level in slow flight was 86,1 dBA, in slow flight with angle of attack -2° was 83,4 dBA, in slow flight angle of attack -4° was 83,2 dBA, is slow flight with high RPM was 88,1 dBA, and in cruising regime 76,9 dBA. The highest noise level was measured in the last case at high RPM. Usually propeller noise becomes considerable with higher RPM compared to low RPM.

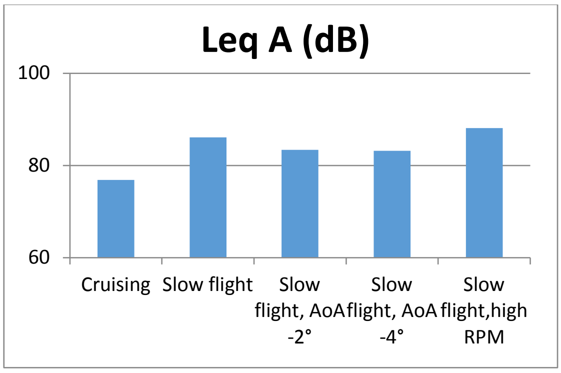

Fig.9. Equivalent Sound level in slow flight and cruising, A-weighting

3.3.5. Discussion

During unusual attitude flight it was confirmed that dominant noise source on this type of aircraft is a power plant. While performing slip, traverse, asymmetric flight and slow flight, overall sound level increased comparing to the one in cruising regime, due to change in propeller angle of incidence, control surfaces settings, change of power setting and propeller control levers position as well as changes of airspeed and altitude. At the same time most noticeable changes were in low frequency band up to 100 Hz. In general low frequency noise has significant acoustic energy in the frequency range 8 to 100 Hz. It is hard to muffle and spreads easily in all directions.

Since the levels up to 70 dBA are considered to be good for the acoustic conditions in cabin, and levels above 90 dBA are unacceptable, from the results it can be concluded that during unusual attitude, levels of cabin noise are mostly unacceptable and can result in fatigue for instructors and students, which are the ones who utilize this type of aircraft the most [5].

Dominant noise source on a small piston engine aircraft is generally a power plant. Engine and propeller produce high levels of noise which efficiently mask other sources of noise on this aircraft. So when planning about the methods and procedures of controlling and reducing the noise this should be taken into consideration. Amount of propeller noise, transmitted into the cabin, should be controlled and the best way to do it is the use of absorptive materials in the acoustic insulation of aircraft interior parts such as seats, doors, floor and ceiling. Indirect combustion noise can be damped with extension of exhaust pipe and with mounting silencers of high quality.

Considering the construction of Piper Seminole, the one used for measurements in this paper, and inability of further isolation of its interior, the only way of reducing interior noise is use of headphones with active noise reduction.

5. CONCLUSION

The data collected, analyzed and presented in this paper show significant noise change in both the levels and spectra generally due to increased and asymmetric loading of the propeller blades during an unusual attitude flight, compared to attitude in regular cruising flight which is confirmed with the results in low frequency band gained with octave band measurements. Similar results were achieved with A-weighting function from which can be seen noise level increase during unusual flight attitude in all measurements.

The most noticeable changes in noise levels and spectra can be seen in low frequency band up to 125 Hz, whereas differences in noise levels are up to 30 dB. In frequency range from 125 Hz to 16 kHz higher noise levels in unusual attitude compared to cruising attitude are from 7 dB to 20 dB. Compared to cruising attitude, the noise levels during unusual attitudes all show an average increase up to 15 dB, which can be heard in flight as distinctive change in both levels and spectra.

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