Active Noise Control Of A Single Engine Light Aircraft Cabin

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Abstract: Active noise control (ANC) shows success and potential in a growing number of commercial applications, one of which is aircraft cabin noise reduction. With the exception of utilising ANC headsets, light aircraft, which to date offer a high noise environment, have been somewhat overlooked. The importance of weight minimisation also prevents installing copious quantities of dampening and insulation materials as a passive noise control measure. While headsets are a pilots' necessity and an obvious target for "localised" noise reduction, they are not conducive to either operator or passenger comfort. High noise levels not only render communication difficult but also contribute towards stress and fatigue. A more globalised region of reduced noise will be less restrictive and no doubt provide the occupants with more freedom of movement and overall comfort. Light aircraft operators boasting quieter cabins with a focus on customer comfort will no doubt have a distinct commercial advantage.

INTRODUCTION

Using flight trials and laboratory experiments as a basis, this paper will discuss the introduction of ANC into a four seater Piper Archer. Existing noise levels, objectives, equipment used, methods of approach and results to date are reviewed, as well as the remaining work required to achieve the final goal.

METHOD

The ANC controller used throughout this project was a Casual Systems six channel feedforward device, well suited for the control of tonal type noise as evident in propeller aircraft. Propeller aircraft however also produce a large amount of broadband noise, so it was therefore necessary to produce a "cleaned" reference signal. "Cleaning" was achieved by placing a pickup alongside the flywheel gear teeth which then electronically generated a tracked fundamental and its associated harmonics, with the appropriate weighting to emulate the interior spectrum.

A digitised wave file, generated from the recorded interior noise, was audibly compared to an edited version with the BPF, and first three harmonics successively removed. This digital notch filtering allowed a subjective evaluation of potential performance.

Achieving the necessary volume velocity at low frequencies is a significant issue for lightweight control systems. A speaker outside of its range of linear performance, while reproducing the low frequency fundamental blade pass frequency (BPF), generates higher order harmonics. These spurious harmonics, coincide with the BPF harmonics, causing control difficulties. It was therefore necessary to design a speaker enclosure with optimised performance at the fundamental frequency. Using the Helmholtz principle, both single and double ported enclosures were designed and built specifically for the task. While these enclosures were too big to be considered for continued use within the confines of an operational aircraft they were ideal for laboratory experiments and an initial "overkill" approach for early flight trials.

RESULTS

Ground trials measured the overall noise level at the pilots' location at 113dB (97dBA). The modal distribution within the cabin, considered for transducer and controller placement, was found to be highly damped, with no obvious resonance peaks. The BPF was at 77Hz, with harmonics at 154Hz, 231Hz and 308Hz. Later removal of higher order harmonics was to demonstrate negligible improvement in audio comfort.

Simple laboratory experiments were conducted inside an anechoic chamber to evaluate the performance of the Active Noise Controller with respect to the task at hand. Initially a single 77 Hz tone (with harmonics added progressively) was controlled with a speaker 2m away and a mid point error sensor. This demonstrated that
while good control was achieved at the error location, it was very localised and at the expense of increased noise elsewhere. Replay and control of the flight data is presented in figure 1 below.

![Graph](image)

**FIGURE 1.** Control of flight data under laboratory conditions

The experiments were then moved to a Cessna cabin where the fundamental and the harmonics were digitally generated via a single interior speaker. With three error sensors and speakers utilised to control the noise around the envisaged occupants' head space, the active noise control was extremely localised. Each error sensor demonstrated up to 9dB of overall reduction, but unless an ear was within a few millimeters of the error sensor and a finger firmly in the other, the noise levels were far worse. This technique was not considered to have sound market value or be an attractive option to headphones. As previously detailed active control of noise in anechoic or semi anechoic enclosures can be extremely localised. In reverberant fields however optimal placement of the error sensor, making use of the modal characteristics of the environment can obtain a more globalised level of control. This however may lead to microphone placement being ergonomically unfeasible. To counteract this problem, this project is considering the use of energy density probes, which control on potential (pressure) energy and kinetic (pressure gradient) energy, offering distinct improvement over the limitations of microphone placement.

**CONCLUSION AND FUTURE DIRECTION**

Experiments to date lead to the belief that as far as control via speakers and microphones is concerned, it will be necessary to include a large number of speakers and control error sensors with each “performing control field” overlapping the next. Global control within the entire cabin will therefore be a large ask and be akin to designing a sledge hammer to crack a walnut. Since in light aircraft the occupants are not free to get up and walk around, the focus of interest will remain in a zone which will envelope the most usual location of their heads. Future experiments, both in the lab and then in the air will focus on global control by use of multiple speaker arrays and energy density sensing. Subsequent to initial flight trials with the large laboratory speakers, it is a goal to design and permanently install less obtrusive speakers and have a fully operation system towards the end of 1998.

**REFERENCES**


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