Active control of sound in a small single engine aircraft cabin with virtual error sensors

Colin D. Kestell

Department of Mechanical Engineering

Adelaide University

South Australia 5005

Australia

A thesis submitted in fulfillment of the requirements

for the degree of Ph.D in Mechanical Engineering

on the 24th of August 2000

(accepted on 13th November 2000)

Abstract

The harmful effects of aircraft noise, with respect to both comfort and occupational health, have long since been recognised, with many examples of sound control now implemented in commercial aircraft. However, the single engine light aircraft cabin is still an extremely noisy environment, which apparently has been side-lined by both cost and weight constraints, especially with respect to low frequency sound reduction. Consequently, pilots and passengers of these aircraft are still exposed to potentially damaging noise levels and hearing damage can only be avoided by the proper use of ear defenders. Minimisation of the noise around the occupants of the aircraft reduces the dependency of personal ear defenders and is conducive to a more comfortable, hygienic and less stressful environment. This thesis describes the basis of a theoretical and experimental project, directed at the design and evaluation of a practical active noise control (ANC) system suitable for a single engine light aircraft.

Results from initial experiments conducted in a single engine aircraft demonstrated the viability of ANC for this application. However, the extreme noise, the highly damped cabin, the multiple tone excitation, the severe weight limitations and the requirement of air worthiness certification severely complicated the problem of achieving noise reduction throughout the entire aircraft cabin. Compromising the objective to only achieving local control around the occupants still presented difficulties because the region of attenuated noise around the error sensors was so small that a nearby observer experienced no sound level reduction whatsoever.

The objective was therefore to move the control zone away from the error sensor and place a broad envelope of noise reduction immediately around the occupant's head, through the use of "virtual sensors", thus creating the *perception* of global noise control.

While "virtual sensors" are not new (Garcia-Bonito et al. (1996)), they are currently limited to acoustic pressure estimation (virtual microphones) via the initial measurement of an observer / sensor transfer function. In this research, new virtual sensor algorithms have been developed to:

1. minimise the sound level at the observer location
2. broaden the control region,
3. adapt to any physical system changes and
4. produce a control zone that may ultimately follow an observer's head

The performance of the virtual sensors were evaluated both analytically and experimentally in progressively more complex environments to identify their capabilities and limitations. It was found that the use of virtual sensors would, in general, attenuate the noise at the observer location more effectively than when using conventional remotely placed error sensors. Such a control strategy was considered to be ideal for a light single engine aircraft, because it would only require small light speakers (possibly fitted into a head-rest) to achieve a broad control zone that envelopes the region around the occupants' heads.

Statement of originality

To the best of my knowledge, except where otherwise referenced and cited, everything that is presented in this thesis is my own original work and has not been presented previously for the award of any other degree or diploma in any University. If accepted for the award of the degree of Ph.D. in Mechanical Engineering, I consent that this thesis be made available for loan and photocopying.

Colin D. Kestell.

Acknowledgments

This thesis would not exist without the help and invaluable support of my family, the university staff, my peers and my friends.

Diane, my wife, has been extremely supportive in many ways and deserves a special mention, as do my three children, Garreth, Glenn and Beth. They have all been patient, there for me when it counted and have all given me good reason to strive for success.

Professor Colin Hansen has been an ideal supervisor, in terms of professional support, encouragement and by sharing the odd laugh or two. I would also like to thank the examiners (Dr. Scott D. Sommerfeldt and Professor Stephen Elliott) for their constructive criticism, which has helped to improve the quality of this thesis.

Ben Cazzolato has consistently provided invaluable help and advice. My fellow students Robert Koehler, Marc Simpson and Xun Li also deserve a mention as do the administrative and technical staff. All have given help and friendship. I must also mention Clint, who lost his head a couple of times, but held it together when it counted.

David Betteridge of Southern Aircraft Maintenance provided a much appreciated initial opportunity to study aircraft noise first hand and the Sir Ross and Sir Keith Smith fund has generously assisted with the funding of this project.

Thank you all.

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