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Optimisation and Adaptive Control of Aircraft Propeller Synchronisation Angles

David Mark Blunt

A thesis submitted in fulfilment of the
requirements for the degree of Doctor of Philosophy

January 2012

School of Mechanical Engineering
The University of Adelaide
South Australia 5005

Principal Supervisor: Colin Hansen
Co-supervisor: Anthony Zander
External Supervisor: Brian Rebbechi (Defence Science and Technology Organisation)

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Defence Science and Technology Organisation
506 Lorimer Street, Fishermans Bend, Victoria 3207

For my father
Richard Mark Blunt
24 April 1924 – 24 October 2009

Abstract

This thesis provides a new and detailed examination of how the optimum propeller synchrophase angles for minimum cabin noise and vibration vary with different flight conditions, particularly altitude and airspeed, and how, based on these observations, adaptive control techniques could best be employed to further improve the noise-reducing potential of synchrophasing. This has been done through experimental investigations in one AP-3C Orion and two C-130J-30 Super Hercules aircraft.

It is shown, using propeller signature theory, that synchrophasing has significant effects on the average cabin floor vibration and the average cabin sound pressure levels. In the trial aircraft, these effects range between 4 dB and 12 dB at the blade-pass frequency, depending on the flight condition and the aircraft. The effects at individual sensors locations can, however, sometimes exceed 20 dB.

It is also shown that the effects of altitude and airspeed on the optimum synchrophase angles are significant, and that a fixed set of synchrophase angles cannot be optimal for more than a limited range of flight conditions. For example, over the range of altitudes and airspeeds considered in this investigation, a fixed set of angles is shown to produce results that can vary by more than half of the range from the lowest to the highest predicted average sound pressure level at the blade-pass frequency.

Adaptive control of the synchrophase angles using pre-defined look-up tables or active control algorithms are considered, and the latter recommended for their ability to compensate for unknown and variable influencing factors.

Two ranking strategies are developed and employed to identify the number and placement of error sensors for an active control system. Significantly, both strategies identify that the predicted average sound pressure levels at the blade-pass frequency in the trial aircraft could be maintained within 2 dB of the optimum across all considered flight conditions using as few as 3 to 6 well-placed microphones.

A single-input (master propeller tachometer) multi-output (slave propeller synchrophase angles) feed-forward active control system with multiple error sensors (microphones or accelerometers) is developed using propeller signature theory and the Filtered-x LMS algorithm.

Recommendations for further work are also made.

Acknowledgment

The work presented in this thesis was undertaken through the candidate's employment with the Defence Science and Technology Organisation (DSTO) of the Department of Defence, Australia. It is bound by a PhD Intellectual Property Agreement between DSTO and The University of Adelaide dated 2nd day of September 2008.

The work could not have been completed without the support of the Department of Defence, and the personal encouragement of Mr Brian Rebbechi and Dr David Forrester.

Thesis Declaration

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution to myself and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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