Notice of the Final Oral Examination
for the Degree of Master of Applied Science

of

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“Measurement of Aeroelastic Wing Deflections on a Remotely Piloted Aircraft using Modal Strain Shapes”

Department of Mechanical Engineering

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Remote Defence

Supervisory Committee:
Dr. Afzal Suleman, Department of Mechanical Engineering, University of Victoria (Supervisor)
Dr. Curran Crawford, Department of Mechanical Engineering, UVic (Member)

External Examiner:
Dr. Jens Bornemann, Department of Electrical and Computer Engineering, UVic

Chair of Oral Examination:
Dr. Aaron Gulliver, Department of Electrical and Computer Engineering, UVic

Dr. Stephen Evans, Acting Dean, Faculty of Graduate Studies
Abstract

The aerospace industry endeavours to improve modern aircraft capabilities in efficiency, endurance, and comfort. One means of achieving these goals is through new enhancements in aerodynamics. Increased wing aspect ratio is an example of further improving efficiency. However, this comes with new challenges including possibly adverse aero-elastic and aero-servo-elastic (ASE) phenomena. New computational methods and tools are emerging and there is a need for experimental data for validation. University of Victoria’s Centre for Aerospace Research (UVic CfAR) set out to design a 20kg ASE demonstrator using a remotely piloted aircraft (RPA). This aircraft was designed with the intent of exploring coupling between aero-elastic modes including coupling between the short period aerodynamic mode and the first out-of-plane elastic mode of the wing. This thesis discusses the implementation of instrumentation designed and integrated into the ASE RPA demonstrator to monitor the deformation of the highly elastic wing in-flight.

A strain based measurement technique was selected for integration into the ASE aircraft. This choice was made for several reasons including its reliability regardless of outdoor lighting, relatively lightweight processing requirements for real time applications, and higher sampling bandwidth. To compute the wing deformation from strain a method, sometimes referred to as strain pattern analysis (SPA), utilizing linear combinations of reference modal shapes fit against the measured strain was used. Although this method is not new, to the author’s knowledge, it is the first practical application to a reduced scale RPA demonstrator.

The deformation measurement system was validated against a series of distributed static load tests on the ground. Distributed load cases along the wing demonstrated good out-of-plane measurement performance. A case where only load is applied near the root of the wing resulted in the largest error in part as the mode shapes generated are less suited to approximate the resulting shape. In general errors in out-of-plane displacement at the end of the flexible wing portion can be expected to be less than 5%. The displacement at the tip of the wing can be as great as 11% for the left wing whereas the right wing is 4.7%. This suggest an asymmetry between the left and right wings requiring specifically tuned FE models for each to achieve best results. Twist angles presented in tests were relatively small for accurate comparison against
the reference measurement, which was relatively noisy. Generally, the deformation measurement by SPA technique followed the same twist behaviours as the reference. A twist case, unlikely to be seen in flight, provided some insight into twist measurement robustness.

The work presented is merely a small step forward with many opportunities for further research. There is room for improvement of the FE model used to generate the mode shapes in the strain pattern analysis. Initial efforts focused on the flexible spar portion of the wing. With more work improvements could be achieved for the estimation of the rigid wing. Additionally, there was some asymmetry between each wing semi-span, and with some focus on the left wing its results could be improved to at least match that of the right wing. A real-time implementation was not completed and would be particularly interesting for use as feedback for flight control. Study of load alleviation techniques may benefit. Another topic of study is the combination of this method with other measurements to provide more robust, higher performance measurements. Consider for instance the use of a Kalman filter combined with SPA, accelerometers, and perhaps other measurements to create a better understanding of the wings shape.