University of Victoria | Graduate Studies

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

of

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BSc (University of Victoria, 2010)

"Modeling, Simulation, Hardware Development, and Testing of a Lab-Scale Airborne Wind Energy System"

Department of Mechanical Engineering

Friday, January 10, 2020
9:30 A.M.
Engineering Office Wing
Room 106

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

External Examiner:
Dr. Panajotis Agathoklis, Department of Electrical and Computer Engineering, UVic

Chair of Oral Examination:
Dr. Sally Brenton-Haden, Department of Educational Psychology & Leadership Studies, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

Airborne Wind Energy Systems (AWES) harness the power of high-altitude winds using tethered planes or kites. Continuous and reliable operation requires that AWES become autonomous devices, but the wind intermittency forces the system to repeatedly take-off to start, and land to shut-off. Therefore, a common approach to facilitate the operation is implementing Vertical take-off and landing (VTOL). This thesis models and simulates AWES flights working towards the implementation of flight controller hardware and autonomous operation of a demonstrator platform. The Ardupilot open-source autopilot platform provides a convenient tool for modeling, simulation, and hardware implementation of small-scale airplanes. An AWES lab-scale demonstrator was developed to obtain operational insight, get preliminary flight data, and real-world experience in this technology. A quadplane was developed by combining a structurally reinforced glider with VTOL and autopilot components. Its performance is obtained from static and aerodynamic studies and converted into the Ardupilot parameter format to define it in the simulation. An AWES flight model was developed from the ground up to evaluate the performance of a simple flight controller in trajectory tracking. The Ardupilot Softwarein-Loop (SIL) tool expands the simulation capabilities by running the flight controller code without requiring any hardware. This allowed controller tuning and flight plan evaluation with a more advanced fight model. AWES crosswind flight simulation was only possible due to the incorporation of an elastic tether and an ideal winch to the physics model. As a result, different trajectories and configurations were tested to find the optimal parameters that were uploaded to the flight controller board. The operational capabilities of the AWES demonstrator were expanded with a flight testing campaign. By targeting individual objectives, each test gradually increased its complexity and ensured that the flight envelope is safely expanded. The results were validated with the simulation before moving on to the next flight test. The testing campaign is still underway due to challenges and limitations presented in the legal aspect of operating the quadplane. However, preliminary flight tests in VTOL mode have been completed and were consistent with the simulated results in terms of autonomous waypoint navigation and attitude control.