Aerodynamic Characteristics of a Generic Micro-Aerial Vehicle with and without Propeller Interactions

Jasmine Warner

Supervisors: Prof. Dries Verstraete

THE UNIVERSITY OF SYDNEY

School of Aerospace, Mechanical and Mechatronic Engineering
The University of Sydney

A thesis submitted to The University of Sydney in fulfilment of the requirements for the degree of *Bachelor of Engineering Honours*

Jan 2022

Declaration

I, Jasmine Warner, hereby declare that this thesis submission titled *Aerodynamic Characteristics of a Generic Micro-Aerial Vehicle with and without Propeller Interactions* is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of the University or other institute of higher learning, except where due acknowledgement has been made in the text. Specifically, the work I contributed consists of:

1. Conducting the literature review
2. Producing a 3D model of the generic micro aerial vechicle
3. Wind tunnel testing of the generic micro aerial vechicle model
4. Analysing data of wind tunnel results; and
5. Writing this thesis report.

Assistance was received from my supervisor in the areas of:

1. Distinguishing relevant literature in respect to this thesis
2. Indicating critical software required; and
3. Ameliorating this thesis through constant feedback.

Jasmine Warner *Author*	Date
Prof. Dries Verstraete *Supervisor*	Date

Acknowledgements

Aerodynamic Characteristics of a Generic Micro-Aerial Vehicle with and without Propeller Interactions

Abstract

Executive Summary

Todo list

Table of contents

List of figures

List of tables

List of abbreviations

ZK Zero-Knowledge.

zk-SNARK Zero-Knowledge Succinct Non-interactive Argument of Knowledge.

ZKP Zero-Knowledge Proof.

Glossary

Verifiable Computation A recent branch in Computer Science relating to the verification of computation, possibly done by a malicious, dishonest actor.

Chapter 1

Introduction

Unmanned aerial vechicles (UAV) are used throughout various industries to conduct missions which are either dangerous, difficult or tedious for humans to perform. The development of technologies and demand for smaller aerial vechicles has lead to the development of Micro aerial vehicles (MAV) [?]. MAV's will become evermore important for both commerical [?] and millitary [?] [?] use as advancements are made in navigation systems, cooperative control of multiple MAV's, advanced vision systems, embedded computational systems and navigational systems.

MAV's do not have a standard guidelines for There are three main categories of MAV, these are fixed wings [], rotary wings [] and flapping wings [].
With the increased complexity of MAV designs, there has also been increased interest in the reasearch and design of optimized MAV models [?]. Current methods do not produce validated, optimised and reliable designs which maximise the performance for the relevant purpose it is created for. In this area software designed to numerically optimise models based on aerodynamic properties, which are in turn mathematically determined are being used. The low Reynolds number that MAVs fly at and the influence of propeller effects on the rest of the MAV are currently unvalidated with physical wind tunnel testing. This main goal of this thesis therefore aims to fill in this gap.

cite

Many groups of research have created software to optimize MAV's by using optimization algorthims such as generic algorthims, non-dominating sorting generic algorithms, particle swarm optimization and sequential quadratic optimisation programs. While some have accounted for low Reynolds numbers and even fewer, propeller interaction effects. None have validated these results with physical testing. These effects are

cite

expected to greatly influence the aerodynamics of MAV designs and both aspects of flight are currently unaccounted for together in physical wind tunnel testing.

1.1 Background

1.1.1 Proliferation of MAV's in the Aerospace Landscape

UAV's have existed for centuries and have been predominately used for survellience and millitary purposes . The recent shift to the miniturization of components, systems and aerial vehicles has already influenced the military sector with several developments underway to reduce visibility of reconansance aircraft and reduce the likelihood of aircraft being detected during missions. What started as a small initial interest in smaller and smarter drones has resulted in exponential growth in the sector . This coupled together with the growth in camera sensors and computer development, has led to the exponential growth in the capabilities of MAV seen today. Where an inital drone supported only low camera resolution with meagre flight times, today incoporates several systems such as gyrostabilisation, GPS capability with waypoint guidance, beyond the line of vision control, speeds of 70 km/h with a 30 minute flight time and a 20 megapixel camera. (DJI Phantom 4).

paper

ld exam-
s)

Phantom

1.1.2 Limitations of Current Developed MAV

1.1.3 The General Micro Aerial Vechicle

1.1.4 Optimization Techniques and Validation

Many non-standard aircraft designs are evaluated using software in order to analyse aerodynamic characteristics and then optimized through a variety of typical software engineering methods such as the particle swarm method. These procedures are typically used as non-standard aircraft designs are more tedious to design and even more complex to setup and test than compared with standard aircraft designs.

There are many studies which have outlined methodologies for accurately determining the forces on fixed wing MAV under low Reynolds number flow streams [**?**]

1.2 Problem Statement

MAV's are set to increase the ability to conduct a variety of missions which predominately have military or survellience objectives (todo: examples). In the past troopers would venture on dangerous missions in order to "hopefully" gather useful information while risking their lives (todo: cite paper). Survellience was conducted initally from hot air balloons, again risking human lives. Later aircraft (mainly helicopters) would be used, costing companies large sums of money in order to survey from a birds eye view. Today drones and UAV's often conduct this work (within certain limits due to range and flight time). The next major technology jump sees the optimization and miniturization of these aircraft to produce MAV's.

MAV's fit a niche and growing market. These aircraft are mainly used for military purposes due to the MAV's main deffering attributes; its smaller size, lower radar visibility and lower noise output.

With MAV design becoming one of the fastest growing areas of development in the aerospace industry, there comes an increasing need to have accurate experimental data in order to validate, simulate and model the numerous MAV configurations being investigated.

MAV's

1.3 Objectives

The objectives of this thesis are as follows:

1. To carry out a review of current published literature and determine areas with insufficient or no research avaliable for further development and research.

2. To design and produce a 3D model of a generic micro aerial vechicle with interchangable empennage.

3. To conduct wind tunnel testing of the generic micro aerial vechicle model with and without propeller effects.

4. To analyse data of wind tunnel results and detail the affect that propeller effects have on general micro aerical vehicles.

1.4 Outline

An outline of the proposed final submission is listed below, however is subject to change.

- Chapter 2: Background and literaure review of relevant topics and reasearch for this thesis
- Chapter 3: Proposed setup of analysis
- Chapter 4: Implementation
- Chapter 5: Results
- Chapter 6: Discussion
- Chapter 7: Conclusion

Chapter 2

Background

This section outlines the core theory and topics which are relevant for the optimization of MAV's.

2.1 Low Reynolds Number Effects

2.2 Propeller Wing Interaction

2.3 MAV Optimization

2.3.1 Wing Planform

2.3.2 Tail Planform

2.4 Non-Linear Lift Distribution

2.5 Stability

Chapter 3

Progress

References

[] Chaturvedi, S. K., Sekhar, R., Banerjee, S., Kamal, H., and Author, C. Comparative review study of military and civilian unmanned aerial vehicles (uavs). *INCAS BULLETIN*, 11:183–198, 2019. ISSN 2247-4528. doi:10.13111/2066-8201.2019.11.3.16.

[] Fan, J., Li, D., and Li, R. Evaluation of mav/uav collaborative combat capability based on network structure. *International Journal of Aerospace Engineering*, 2018, 2018. ISSN 16875974. doi:10.1155/2018/5301752.

[] Liu, X. F., Guan, Z. W., Song, Y. Q., and Chen, D. S. An optimization model of uav route planning for road segment surveillance. *Journal of Central South University 2014 21:6*, 21:2501–2510, 2014. ISSN 2227-5223. doi:10.1007/S11771-014-2205-Z. URL `https://link.springer.com/article/10.1007/s11771-014-2205-z`.

[] NONAMI, K. Prospect and recent research development for civil use autonomous unmanned aircraft as uav and mav. *Journal of System Design and Dynamics*, 1:120–128, 2007. doi:10.1299/JSDD.1.120.

[] Roberts, B., Lind, R., and Kumar, M. Polynomial chaos analysis of mav's in turbulence. *AIAA Atmospheric Flight Mechanics Conference 2011*, 2011. doi:10.2514/6.2011-6214.

[] Ward, T. A., Fearday, C. J., Salami, E., and Soin, N. B. A bibliometric review of progress in micro air vehicle research:. *http://dx.doi.org/10.1177/1756829316670671*, 9:146–165, 2017. ISSN 17568307. doi:10.1177/1756829316670671. URL `https://journals.sagepub.com/doi/10.1177/1756829316670671`.

Appendix A

Work Health and Safety

Work Health and Safety is a significant concern to all workers. Although seemingly simple in nature and low in risk, office jobs have their fair share of long-term health risks that must be considered. This section will analyse a number of Work Health and Safety concerns in the modern office that applies to this ESIPS placement at Accenture. Some that will be discussed include physical health, COVID-19, and mental health.

Impact

Likelihood

	Negligible	Minor	Moderate	Significant	Severe
Very Likely	Low Med	Medium	Med Hi	High	High
Likely	Low	Low Med	Medium	Med Hi	High
Possible	Low	Low Med	Medium	Med Hi	Med Hi
Unlikely	Low	Low Med	Low Med	Medium	Med Hi
Very Unlikely	Low	Low	Low Med	Medium	Medium

Fig. A.1 Risk matrix. From `https://www.armsreliability.com/page/resources/blog/beyond-the-risk-matrix`.

A.1 Physical Health

In a standard office, work is often long, repetitive, and stationary. Bad posture, uncomfortable chairs, mispositioned monitors, wrist strain over cramped keyboards, poor lighting or glare are just a few of the most common risks and hazards to physical health.

At Accenture and home, the following precautions were observed:

1. Education on the proper position to work in was studied from A.2. Notably, the height of the chair is set to the appropriate height to allow feet to rest in an almost 90 deg angle, the top of the monitor edge at eye level, and the monitor slightly tilted up to equalise the distance to all corners of the screen.
2. Good chairs were selected. I purchased a Herman Miller Aeron chair for work at home, known for its world-renowned ergonomics.
3. Used a second external monitor to relieve neck strain, as it is possible to adjust the monitor's position to the optimal position. This also provided a significant productivity boost. The brightness was also adequately adjusted to bring the most comfort to the eyes.
4. A standing desk was purchased for working at home.
5. Regular breaks were taken with the team during the time at the office.
6. An ergonomic keyboard, the Kinesis Advantage 2, was used to relieve wrist strain and improve productivity with the features such as macros.

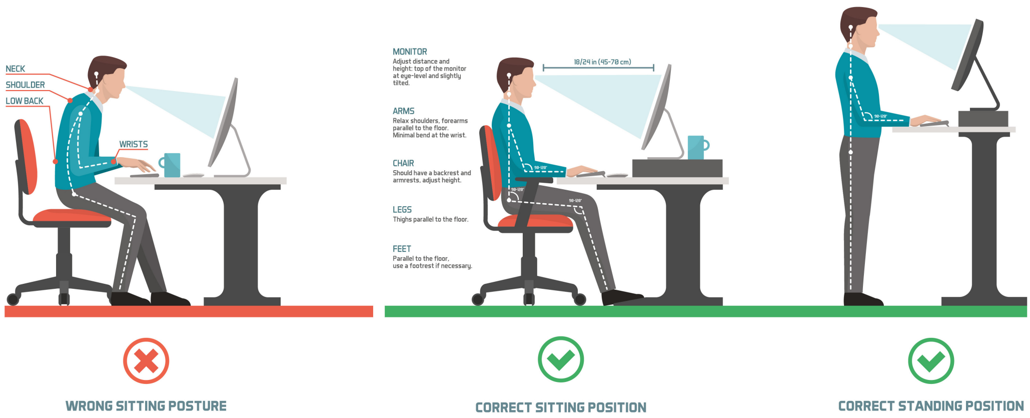

Fig. A.2 Best posture at a desk. From: `https://healthandbalance.com.au/workstation-desk-posture-ergonomics/`

Although there are many sources of long-term physical issues, these can be easily managed with awareness and mitigated effectively, resulting in a low level of risk.

A.2 Covid-19 precautions

Covid-19 has undeniably impacted the world in many ways. This highly infectious disease caused major lockdowns and shifted work from the office to the home for extended periods. In order to follow national and state requirements, Accenture and employees worked remotely and suspended office visits. Return to the office was first announced in mid-November, where a number of precautions were followed:

1. All state and national requirements were followed, including masks in public indoor areas and on transport, QR code check-ins in all locations required, and mandatory bookings for visits to the office.
2. Social distancing in all public areas.
3. Sanitising hands on every entry to the office.
4. Disallowing guest visits to the office.

Although the severity of symptoms one suffers from contracting Covid-19 vary wildly in the younger age group, the potential to be sick for a week or more, in addition to the mandatory self-isolation period, is highly disruptive to work and the greater population. As such, the threat of Covid-19 results in high risk.

A.3 Mental health

Mental health is an often under-looked part of one's health. It varies greatly from person to person, and many factors play into one's overall mental health, including social health, work-life balance, and financial status. Without careful consideration, planning and awareness of one's mental health, the employee's productivity may drop sharply.

A number of precautions were taken to care for my mental health:

1. Ensuring I was enjoying the work I was doing. I transferred internally between teams to find more exciting work that I could grow and learn in while also finding a more relevant thesis topic aligned with my interests.

2. Coming into the office when practical. Although there were many days where I was the only team member in the office, being able to experience the office, grab hot drinks in the morning with colleagues, and work in an environment separate from home was very beneficial.

3. Preventing work hours from extending into my personal time too often.

Mental health is a complex risk to quantify since it is difficult to measure and includes many factors. Overall the onus is mainly on the employee to ensure they take the proper precautions and use the available resources such as sick leave or personal time off. Particularly with the challenging program that is ESIPS, this risk is categorised as a moderate risk.