DESIGN AND DEVELOP A VERTICAL TAKE-OFF AND LANDING FIXED-WING HYBRID UNMANNED AERIAL VEHICLE

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2019

DESIGN AND DEVELOP A VERTICAL TAKE-OFF AND LANDING FIXED-WING HYBRID UNMANNED AERIAL VEHICLE

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A report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Mechatronics Engineering with Honours

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2019

DECLARATION

I declare that this thesis entitled "DESIGN AND DEVELOP A VERTICAL TAKE-OFF AND LANDING FIXED-WING HYBRID UNMANNED AERIAL VEHICLE is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have checked this report entitled "DESIGN AND DEVELOP A VERTICAL TAKE-OFF AND LANDING FIXED-WING HYBRID UNMANNED AERIAL VEHICLE" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

Signature : ....

Supervisor Name : ....

Date : ....

DEDICATIONS

To my beloved mother and father

ACKNOWLEDGEMENTS

First of all, I would like to express my appreciation to Dr. Hairol Nizam bin Mohd Shah on guiding me all along the project here in terms of technical support and documentation guidance. Moreover, I would like to show gratitude to Dr. Lee Shian who is proficient in Aerospace Engineering, to guide me all along during designation and aircraft building phase. I appreciated both Dr.Hairol and Dr. Lee who inspired me and keep me motivated in this project.

I would like to say thank you for all the supports either physically or mentally, from my beloved friends and family. They had lent me a hand without any second thought during this project, whenever I need it.

Building an aircraft is not easy, especially for me, whom not studying Aerospace Engineering as major of degree, but these people lead me in it, with the aid of my Mechatronics Engineering skills that trained in Universiti Teknikal Malaysia Melaka, these all made this project from impossible to possible.

ABSTRACT

Applications using Unmanned Aerial Vehicle (UAV) is growing since the past decade in both civilians and military industry. This robot has promising advantages in performing various tasks, especially without risking any single human life. Meanwhile, different requirement of various tasks leads to various types of UAV being designed to overcome with. This project focused on design and develop UAV with combination between the fixed-wing aircraft and the multirotor drone, named as fixed-wing hybrid type of UAV. Reviews on others work relevant to design and develop fixed-wing hybrid UAV has been done to come out with solid ideas to complete this project. There are plenty types of configurations available, thus they have been analyzed for selection of suitable ones to be involved according to design requirement established in early stage of this project. The results obtained in this project is a fixed-wing hybrid with a quadcopter UAV is designed and built to fly. All the calculations, fabrication steps, materials chosen and electronics components are included in this report. At the end of this project, flight evaluation is done on the flight test of UAV. There are a few suggested future work stated as well for further improvement for this project.

ABSTRAK

Aplikasi yang menggunakan Kenderaan Penerbangan Tanpa Manusia (UAV) berkembang sejak dekad yang lalu dalam kedua-dua sector awam dan industri ketenteraan. Robot ini mempunyai kelebihan menjanjikan dalam melaksanakan pelbagai tugas, terutama tanpa mengambil risiko terhadap sebarang kehidupan manusia. Sementara itu, pelbagai keperluan bagi berbagai tugas membawa kepada pelbagai jenis UAV yang direka untuk diatasi. Projek ini memberi tumpuan kepada reka bentuk dan membangunkan UAV dengan gabungan antara pesawat sayap tetap dan drone multirotor, yang dinamakan sebagai jenis hibrid tetap jenis sayap UAV. Ulasan mengenai orang lain yang berkaitan dengan reka bentuk dan membangunkan UAV hibrid tetap sayap telah dilakukan untuk menghasilkan idea-idea kukuh untuk menyelesaikan projek ini. Terdapat banyak jenis konfigurasi yang tersedia, oleh itu mereka telah dianalisis untuk pemilihan yang sesuai untuk terlibat mengikut keperluan reka bentuk yang ditetapkan pada peringkat awal projek ini. Keputusan yang diperolehi dalam projek ini adalah hibrid sayap tetap dengan UAV quadcopter direka dan dibina untuk terbang. Semua pengiraan, langkah fabrikasi, bahan terpilih dan komponen elektronik dimasukkan ke dalam laporan ini. Pada akhir projek ini, penilaian penerbangan dilakukan pada ujian penerbangan UAV. Terdapat beberapa kerja masa depan yang dicadangkan dan juga penambahbaikan untuk projek ini.

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INTRODUCTION

1.1 Introduction

The advance of technologies ease human to perform a lot of difficult, dangerous, time-consuming work with being there, we call them robots. A robot is a machine capable of carrying out a complex series of actions automatically, especially one programmable by a computer. One of the most commonly known flying robots nowadays is Unmanned Aerial Vehicles (UAVs), which also known as drones. According to Market And Market Research Private Limited's analysis, drones market is expected to grow from USD 13.81 Billion in 2016 to USD 48.88 Billion by 2023 [1].

Almost every drone has featured in taking photos and videos, therefore, drones are used in photography industries, they are mainly used in the defense industry worldwide. Border patrol and surveillance missions are always risky and full of unknowns, these made flying robots the best option to perform the task without risking any humans' life while protecting the other humans. In the coming 10 years' time, the Pentagon plans a USD 40 billion budget in purchasing more than 700 medium- and large-size drones, according to a Congressional Budget Office study [2]. Based on the report of CNET, the US Army is getting tiny personal surveillance drones as part of a $2.6 million contract with Flir, a thermal imaging, and technology company[3].

Generally, there are four types of UAV can be found, Multi-Rotor, Fixed-Wing, Single-Rotor, and Fixed-Wing Hybrid. Among those 4 types of UAVs stated, Multi-Rotor type is the most popular drone type, due to the financial barrier to entry in the multirotor market is low enough for the public, moreover it gives users to have much more control over positioning and framing the camera to get you that perfect aerial photo shot. Although there are plenty of pros in using multi-rotor type UAVs, there are cons too. It has small payload capacity and short flight time (normally around 20 mins flight). Hence, fixed-wing hybrid UAV is chosen to be developed in this project because this type of drone is capable to perform vertical take-off and landing (VTOL) which requires minimal spaces to take-off and land. In addition, it has significantly longer flight endurance and distance compared to multi-rotor drones.

Contributions from me will be designing the structure of UAV, in the sense of choosing configurations of aircraft, calculating the size of aircraft parts needed and thrust power required, then manufacture according to own design.

1.2 Problem Statement

Border patrolling has been troubling mankind for centuries as it needs huge manpower to be done, yet it is quite dangerous during patrolling when a job needs high efficiency while easing the process safely, robots are the best option to replace human power in it. There are a few requirements for a robot need to be achieved in order to do border patrolling.

1. Able to travel in long distance.
2. Long endurance in use.
3. Travel at high speed to reach a destination in a short time.
4. Do not have any constraint on the reachable place or travelable route.

With all the requirements stated above, fixed-wing hybrid UAV is the most suitable choice to be designed to solve this problem.

There a few problems need to be solved during designation and building a fixed-wing hybrid UAV as stated below.

1. Design and functional requirements for fixed-wing hybrid UAV.
2. Electronics parts needed to achieve functional requirements.
3. Structure and size of UAV to fulfill the design requirements and functional requirements.
4. Materials to fabricate UAV.

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1.3 Objectives

1. To design a fixed-wing hybrid UAV then draw in SolidWorks.
2. To build a fixed-wing hybrid UAV based on own design and control by remote control.
3. To evaluate flight performance with flight test.

1.4 Scope

This project is focused on designing and developing a dual system fixed-wing hybrid UAV that is powered by lithium battery ion, controlled by a pilot using a remote control. The design will need to consider flight endurance, mission range, and maximum airspeed. After designation phase, it will be built and evaluated with flight test later. Meanwhile, all parameters related in designing a remote controlled aircraft is considered besides crew weight and fuel weight (due to lithium-ion battery will not decrease in weight while providing energy). The parameters are stated below.

1. Estimation of take-off weight.
2. Estimation of total drag coefficient, C_D, cruising lift coefficient, C_{Lc}
3. Wing reference area, S_{ref}
4. Electrical motor propulsion thrust/power
5. The weight of components and UAV's weight

However, during designation phase, manufacturability and cost are main concerns, hence, optimization needed between the efficiency of UAV structure and those two concerns.

1.5 Motivation

While choosing fixed-wing hybrid UAV as this final year project, including two general motives which are motives of choosing UAV and motives of choosing a fixed-wing hybrid type of UAV.

As mentioned in the Introduction part of this chapter, drones' market growth is so significant in past years, whereas it is going to grow even more in the coming ones. Goldman Sachs reported that the total expenses on UAV will exceed USD 100 billion by the year 2020. Among all the spenders on drones, the defense sector is the largest group, which is expected to spend around USD 70 billion between 2016 to 2020. The commercial business also trying to implement usage of drones in recent years, hence this sector shows the fastest growth opportunity, which projected to hit USD 13 billion of total spending between 2016 and 2020 [1]. This indicates that drones are a trend of technologies developed with its enormous market value. This type of UAV is currently in the developing phase, it is not available on the common market yet so it’s totally worth for us as a Malaysian undergraduate engineer to spend time on developing it. Meanwhile, the UAV system helps police, fire and other first responders save lives in the event of natural disasters, locate missing children and help fight wildfires too. It assists the coast guard in rescue missions and helps the border patrol [4].

Fixed-wing hybrid UAV is a type of drones that generate lift by forwarding airspeed, meanwhile capable of VTOL. This hybrid UAV enable it to carry higher payload because lifting by the aerodynamic lift of an airfoil is much power saving. This property also allows it to have longer flight endurance, meaning that it has a larger mission range. By comparing to multi-rotor drones, it has a higher airspeed, in other words, it reaches target location much faster. Although this hybrid UAV will not have better endurance, faster airspeed not power efficient compared to fixed-wing UAV, because of the vertical propulsion parts are causing a lot of drag, but this UAV comes out with another pro, it is capable of VTOL. VTOL allows users to launch this UAV without a spacious flat ground (a runway). This property makes UAV possible to launch in a small, uneven ground such as jungle. Other than launch, landing space is a concern as important as launching space. Fixed-wing hybrid UAV can do landing in almost any area as long as there are no obstacles in landing range (around 50 percent larger than the wingspan of UAV).

Chapter 2

LITERATURE REVIEW

2.1 Overview

This chapter presents theoretical backgrounds which are related to this project. Many journals and conference papers related to this research are studied and evaluated based on a few specific criteria. Then, the most suitable setup is chosen to be used in this project.

2.2 Unmanned Aerial Vehicle (UAV)

A UAV, also known as a drone, is an aircraft that outstands from a traditional aircraft, where a human pilot is unneeded. This type of vehicle is either operated by a pilot by using a telemetry control system or controlled autonomously by microprocessors in it [5]. Applications of UAV had already included in fields like scientific research, environmental observation, law enforcement, disaster support, and industrial support [6]. In [7], there are three main types of drones available, fixed-wing system, multirotor system, and other systems. A multirotor system is a type of drone equipped multiple rotors for stability purposes. Without any doubt, the multirotor drone is the most common one in the market, such as DJI Phantom, Parrot AR Drone, Hubsan x4 Drone, etc. It is due to its easy configuration to build and use, capable of VTOL and high stability. The other system drones are the type that does not use fixed-wing nor multirotor or using both, which make them cannot be classified into two previous types. Example of this type of drones is ornithopter, fixed-wing hybrid and unmanned balloon. shows the pros and cons in a few types of drone.

Table 2.1 Pros and Cons of different types of drone[8]

	Pros	Cons	Typical Uses
Multi-Rotor	• Accessibility • User control friendly • Capable of VTOL and hovering • Good stability for photographing • Usable in a confined area	• Short flight endurance • Small payload capacity	Aerial Photography and Video Aerial Inspection
Fixed-Wing	• Long flight endurance • Large area coverage • Fast in forward transitioning	• Runway needed to takeoff and landing • Unable to hover • More difficult in piloting • Expensive to fabricate	Aerial Mapping, Pipeline and Powerline inspection
Fixed-Wing Hybrid	• VTOL and long flight endurance	• Not perfect at either hovering or forward transitioning • Still in developing phase	Drone Delivery

2.3 Fixed-Wing Aircraft

In the aviation industry, fixed-wing is used to define an aircraft with fixed yet static wings that use forward airspeed to generate lift force [7]. The best example of this kind of aircraft is the civil aviation, such as Boeing and Airbus, the most known aircraft. In [9], designing a fixed-wing aircraft, there are some configurations as below needed to be chosen.

2.3.1 Wing types

The most common wing type on fixed-wing aircraft is a monoplane, also known as a one-wing plane. Conventional monoplane has advantages like greater manufacturability, more predictable aerodynamical performance and, higher stability, lower induced drag, better movement capacity, and faster speed. Figure 2.1 refers to a different kind of wing type configuration for monoplanes. While

Table 2.3 refers to the comparison of wing types by using merit system.

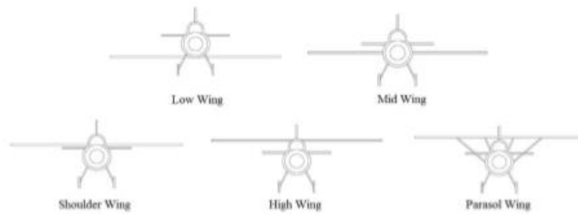


Figure 2.1 Wing types for Monoplanes

Table 2.2 Comparison of wing types[9]

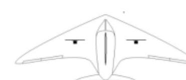
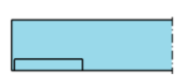
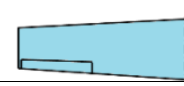
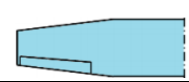
Figure of Merit	Score of Factor	Monoplane	Biplane	Flying Wing
				
Weight	40	2	1	2.5
Lift/Drag	30	2.5	3	2.5
Stability	10	3	3	1.5
Manufacturability	10	2.5	1.5	1.5
Aerodynamics Performance	10	3	2	2.5
Total	100	240	2.5	230

Table 2.3 Comparison of the straight wing [10]

Figure of Merit	Score of Factor	Rectangular	Tapered	Prismatic mid-Section
				
Manufacturability	60	5	3	4
Strength	20	4	5	5
Aerodynamic Performance	20	3	5	4
Total	100	440	380	420

Among these configurations, high wing type has the highest lifting capacity whereas rectangular wing is easy to manufacture while maintaining good strength and high aerodynamic performance. Therefore, a rectangular high wing type of monoplane configuration is chosen to develop fixed-wing hybrid UAV in this project.

2.3.2 Tail types

A tail of a plane, also known as a horizontal stabilizer, is a smaller wing that provides lift at the rear of a fixed-wing aircraft. The most common configuration for aircraft's tail is the conventional configuration based on Raymer and his team. It helps in adapting the changes in center of gravity caused by altering in speed and attitude, or when fuel is used during flight, or when a payload is released. Table 2.4 shows merits in term of weight, drag, and stability of three types of tails.

Table 2.4 Comparison of tail types [10]

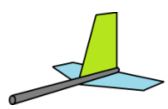
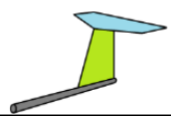
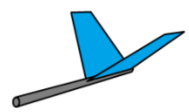
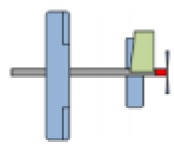
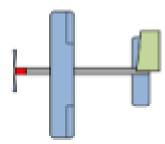
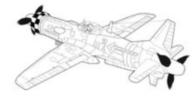
Figures of Merit	Score of Factor	Conventional	V-Tail	T-Tail
				
Weight	55	3	1	1
Drag	20	2	2	3
Stability	25	2	3	1
Total	100	255	170	140

Table 2.4 above clearly shows that the conventional tail type has the best performance among these three types compared. Hence, the conventional tail is chosen in designing UAV in this project.

2.3.3 Motor placement

Table 2.5 indicates that tractor type motor is the best in three types of motor configurations. In the tractor type motor, both propeller and motor are placed on the nose of the aircraft, it helps to maintain the stability and reduces the weight of the whole system. Thus, tractor type motor is the best fit for the design of UAV in this project.

Table 2.5 Comparison of motor types [9]

Figures of Merit	Score of Factor	Pusher	Tractor	Push-Pull
				
Weight	55	3	3	1
Efficiency	45	1	2	1
Total	100	210	255	100

2.3.4 Airfoil selection

Basic shapes of wings and tails in most aircraft are known as airfoils, or sometimes known as aerofoils, are structures with curved surfaces designed to give the best lift to drag ratio (C_l/C_d). While designing airfoil, the angle of attack (AOA) plays an important role as the greater the AOA, the better the aerodynamic characteristics, but it causes a stall at the same time, critical AOA is determined at 15°. Meanwhile, AOA is the angle between the reference line on a body and the incoming flow act on the body. Few types of selected airfoil configurations, as shown in Figure 2.2, is compared in merit form in Table 2.6.

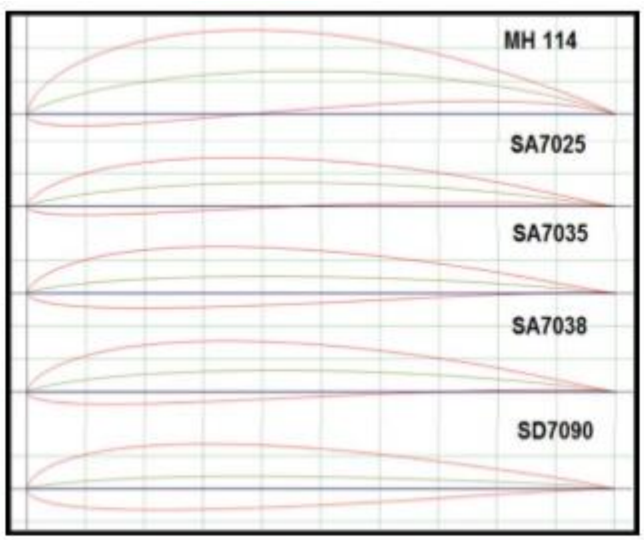


Figure 2.2 Selected airfoil configurations