GENERATIVE DESIGN OF 6 AXIS DRONE FOR WEIGHT OPTIMISATION”

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DECLARATION

I declare that this thesis entitled "GENERATIVE DESIGN OF 6 AXIS DRONE FOR WEIGHT OPTIMISATION" 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.

Signature :

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APPROVAL

I hereby declare that I have checked this report entitled "Generative Design of 6 axis Drone for Weight Optimization" 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

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Date : 05 JULY 2021

DEDICATIONS

To my beloved mother and father

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ABSTRACT

A drone is an Unmanned Aerial Vehicle (UAV). UAV drone is a flying robot that can be remotely controlled through software-controlled flight plans in their embedded systems. UAV drones are equipped with varies state of the art technology such as infrared cameras, GPS, and laser (consumer, commercial and military UAV). The nose part of the UAV drone is the location where the sensors and navigational systems located. The objective of this project is to design and fabricate structure of a UAV drone which achieving the optimization of shape of materials and manufacturing methods and saving cost of materials, parts, and design time for industry. Besides, this project also aimed to achieve multiple explorations and validations of product design of UAV drone which accelerating product development process. The major challenge in this project is to obtain unique structure design of the 6-axis drone through different input applied. In this project, a mechanical structure of UAV drone is fabricated are sketched in Autodesk Inventor and Autodesk Fusion 360. Generative Design is a process of defining the constraints and forces of the imaginary design then the software will calculate all the shape possibilities that satisfies the initial design parameters. The UAV Drone designed according to two regions which are obstacle and preserve regions. The preserve regions define as areas that must exist for the part to function properly. Obstacle regions define as areas that need to be avoided by the generated outcome. The load cases will determine where material is added to ensure that the design of UAV drone meets the performance requirements. Structural Constraints include Fixed, Pinned, and Frictionless. Fixed Constraints can be set to the X, Y, and Z aces. There are three manufacturing options which are Unrestricted, Additive, and Subtractive. There are many types of materials such as ABS Plastic, Titanium, and so on. There are objectives either Minimize Mass or Maximize Stiffness and Safety factor must be selected. Exploration tools like detailed thumbnails, filters, and customizable scatter plots help to find the results that best match UAV drone design, engineering, and manufacturing requirements. The prototype of this generative design of 6 axis drone fabricated by using Selective Laser Sintering (SLS) printing with Nylon material. This generative design has total weight less than 1kg. It optimized maximum stress analysis is 5.028MPa with 83.00%, maximum displacement analysis is 0.666mm with 45.44% and production time is 15.5hours with 61.25% which improve the weight optimization.

ABSTRAK

Dron ialah satu kenderaan udara tanpa pemandu. Kenderaan udara ini adalah satu robot terbang yang boleh dikendalikan dari jauh. Dron dikendalikan melalui rancangan penerbangan yang dikendalikan oleh perisian dalam sistem tertanamnya. Dron UAV dilengkapi dengan teknologi canggih yang berbeza seperti kamera inframerah, GPS, dan laser. Tempat hidung dron UAV adalah tempat semua sensor dan sistem navigasi. Objektif projek ini adalah untuk merancang dan membuat struktur drone UAV yang mencapai pengoptimuman bentuk bahan dan kaedah pembuatan dan menjimatkan kos bahan, bahagian, dan masa reka bentuk untuk industri. Selain itu, projek ini juga bertujuan untuk mencapai pelbagai penerokaan dan pengesahan reka bentuk produk dron UAV yang mempercepat proses pengembangan produk. Cabaran utama dalam projek ini adalah mendapatkan reka bentuk struktur unik drone 6 paksi melalui input yang berbeza. Dalam projek ini, struktur mekanik dron UAV dibuat berdasarkan lakaran Autodesk Fusion 360. Reka Bentuk Generatif adalah proses menentukan kekangan dan kekuatan reka bentuk khayalan maka perisian akan mengira semua kemungkinan bentuk yang memenuhi parameter reka bentuk awal. UAV Dron dirancang mengikut dua wilayah yang merupakan kawasan rintangan dan pelestarian. Kawasan pelestarian menentukan kawasan ini yang mesti ada agar bahagian berfungsi dengan baik. Kawasan rintangan menentukan kawasan yang perlu dielakkan oleh hasil yang dihasilkan. Kes beban akan menentukan di mana bahan ditambahkan untuk memastikan bahawa reka bentuk dron UAV memenuhi syarat prestasi. Kekangan Struktur merangkumi Tetap, Dipasang, dan Tanpa Geseran. Kekangan yang diperbaiki dapat disetel ke X, Y, dan Z .Terdapat tiga pilihan pembuatan iaitu Tidak Terhad, Tambah dan Subtraktif. Terdapat banyak jenis bahan seperti ABS Plastik, Titanium, dan sebagainya. Objektif seperti minimum berat badan atau maximum kekakuan dan faktor keselamatan mesti dipilih. Alat penerokaan seperti lakaran kecil terperinci, penapis, dan plot penyebaran yang dapat disesuaikan membantu mendapatkan hasil yang paling sesuai dengan keperluan reka bentuk, kejuruteraan dan pembuatan dron UAV. Prototaip reka bentuk generik dron ini akan dibuat dengan menggunakan percetakan pencucian laser selektif (SLS) dengan bahan nilon. Reka bentuk generatif mempunyai berat badan kurang dari 1kg. Analisis tegasan maksimum yang dioptimumkan ialah 5.028MPa dengan 83.00%, analisis anjakan maksimum 0.666mm dengan 45.44% dan masa pengeluaran adalah 15.5 jam dengan 61.25% yang meningkatkan pengoptimuman berat.

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LIST OF SYMBOLS AND ABBREVIATIONS

UAV	-	Unmanned Aerial Vehicle
AUVSI	-	Association for Unmanned Vehicle System International
DFMA	-	Design of Manufacturing and Assembly
RPM	-	Revolution per Minute
DFM	-	Design for Manufacture
DFA	-	Design for Assembly
AM	-	Additive Manufacturing
SLM	-	Selective Laser Melting
DMLS	-	Direct Metal Laser Sintering
SLA	-	Stereolithography
SLS	-	Selective Laser Sintering
FDM	-	Fused Deposition Modelling
L	-	Length
W	-	Width
H	-	Height

CHAPTER 1

INTRODUCTION

1.1 Motivation

Unmanned Aerial Vehicle (UAV) is a flying robot that can be remotely controlled through software-controlled flight plans in their embedded systems. Multirotor aircraft is a brand-new platform in small UAVs. This aircraft combined with a main rotor controlled with collective and cyclic pitch inputs, multiple fixed pitch used, variable revolution per minute (RPM) propellers to produce thrust and moments necessary for controlled flight[1]. At this current escalating rate of knowledge growth in the areas of drones and automations, it is convincing to tell that "The best is yet to come" and the technology advancement in robotics will keep on improving to the state where all the physical jobs that done by manpower will be completely change to robotic at a very low cost.

Multirotor aircraft is a generic term that includes all type of drone that in Unmanned Aerial Vehicle (UAV). Quadcopter is the simplest controllable multirotor aircraft in UAV. Quadcopter uses total four rotors which arranged in an equal square pattern[2]. Quadcopter is an unmanned aerial vehicle with 4 rotors. This quadrotor has inherent dynamic nature which make it has good maneuverability. Quadcopters have four inputs which are roll, pitch, yaw, and throttle and six outputs to make it as an under-actuated system[3]. Some common applications are quadcopter for known environment such as traffic monitoring, shipping delivery, geographic mapping, search, and rescue and so on. While choosing a quadcopter, several design considerations must be taken in account, such as weight, payload, and supply of services.

Association for Unmanned Vehicle System International (AUVSI) showed the most promising markets of UAVs are precision agriculture and public safety. Results from the sensitivity analysis of the weight modules showed that geometric and aerodynamics variables are useful to reduce the takeoff weight, and to improve the performance for UAV [4]. UAV had become an integrated tool for measuring and assessing live green vegetation to improve the feature matching and image perspective projection for agriculture[5].

1.2 Problem Statement

This project primarily aimed to design and optimize a 6-axis drone for weight optimization. Drone has limited usage due to heavy weight [5]. Limited type of structure designs of the drone in order to achieve weight optimization [6]. In manufacturing, it had provided a lot of the foundation for innovations. The Manufacture Method of the drone design is the main challenge in accordance to control target like production cost, weight which maintaining both flexibility and fluidity that is required for creative design exploration [7].In this project, High performance in altitude displacement of drone requires not only the flexibility of the drone design but also its endurance. Therefore, every type of Materials used for drone design will give different rates of mechanical properties like tensile strength, stiffness, impact strength and flexural strength [7].

1.3 Objectives

The objectives of this project are:

Objective 1 : To analyze the parameters of 6 axis Drone using Design of Manufacturing and Assembly (DFMA)

Objective 2 : To investigate the generative design of 6 axis drone under different multiple explorations and validations of product design.

Objective 3 : To optimize the design and fabricate the 6 axis Drone prototype for Weight Optimization.

1.4 Scopes of Project

1. This project will only design a 6-axis drone with a total weight of the mechanism not exceeding 1kg.

2. Multiple explorations of structure design achieved through simulations of generative design through Autodesk Fusion 360.

3. Weight Optimization will be investigated by testing different type of displacement, static stress analysis and Design for Manufacturing and Assembly.

1.5 Report Outline

This project primarily aimed to design and optimize a 6 axis drone for weight optimization.This report consists of total five chapters. Every chapter consists of important information of the project. The project report is outlined as below:

Chapter 1 entitled "Introduction". It contains brief introduction to the project. Problems for the project have been formulated and stated in section 1.2. Therefore, motivation, objectives and scopes of project have been stated to give the project a guideline in progression. Chapter 2 is entitled "Literature Review". Various studies have been done in the early stage of this project. It is very important to understand the components beforehand to ensure the project can progress on the right track. This chapter basically discussed about the theory, function about the generative design of 6 axis drone for weight optimization. Chapter 3 is entitled "Methodology". It discussed about the methods and process flow in achieving the research aim and objectives. Each research procedure has been stated including data collection method and usage of Design for Manufacturing and Assembly (DFMA) and Autodesk Fusion 360. Chapter 4 is entitled "Result and Analysis". This chapter is the core of the project. It shows both the conventional and generative design of 6 axis drone and software testing had been carried out to ensure either the data collected can or cannot be accepted. Chapter 5 is entitled "conclusion and recommendation". This chapter concludes the project based on the output of the project and project objectives. Therefore, recommendations for future research have been stated.

CHAPTER 2

LITERATURE REVIEW

2.1 Drone Structure Design

2.1.1 Quadcopter Design

Quadcopter is an aircraft that have 4 motors. It is propelled by total four rotors and capable of vertical take-off and landing. Dr. George E. Bothezat [8] designed a quadcopter which converted from a wings model in 1956. However, early prototypes of the quadcopter suffered from poor performance, required extra pilot workload, poor stability augmentation and limited control authority. The stability of these vehicle with controlled by using electronic control system and electronic sensors.

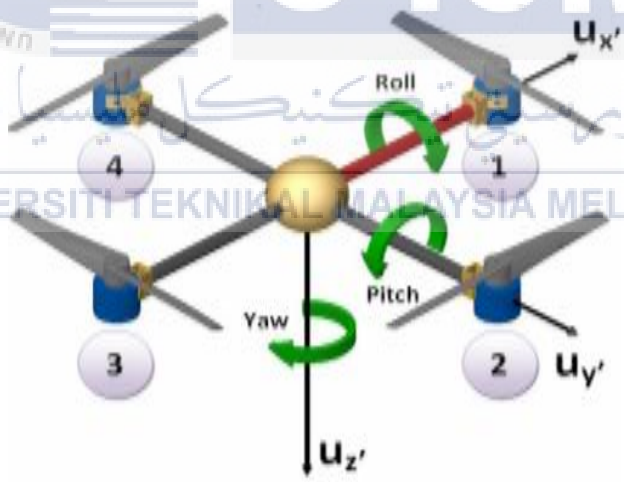

Figure 2.1 Yaw, pitch, and roll rotations of a common quadrotor [8]

Anudeep et. Al. (2014) [8] classified quadcopter in to two categories whereas micro and mini air vehicles. Size and weight are the difference to classify type of the quadcopter. Figure 2.1 shows three type of dynamic parameters which are the angle of pitch, roll and yaw on a common quadrotor model. Each rotor has its own significance in creating thrust, torque, and direction. The propellers which create the thrust to the quadcopter. Two of thrust created are clockwise act as pullers and other two are anti clockwise act as pushers and this resulting the torque become zero. There are another three more dynamic parameters which are angles of yaw, pitch and roll to determine the aircraft's orientation around the aircraft's center of mass to vary the speed of the motors and direction of the quadcopter.

Figure 2.2: Assembled Quadcopter Design [8]

There are many parts in a structure of a quadcopter. The main part of the quadcopter is frame which has four arms as shown in Figure 2.2. There are many components will be attached on the frame which are battery, four brushless DC motors, controller board, four propellers, and different types of sensors. Therefore, the rigidity and weight of the frame must be prioritized to host all the components above. The motors selected must place same distance from the center on opposite sides to avoid any aerodynamic interaction between propeller blades. There are two types of the configuration normally use in the quadcopter which are plus and cross configuration.

2.1.2 Hexa-copter Design

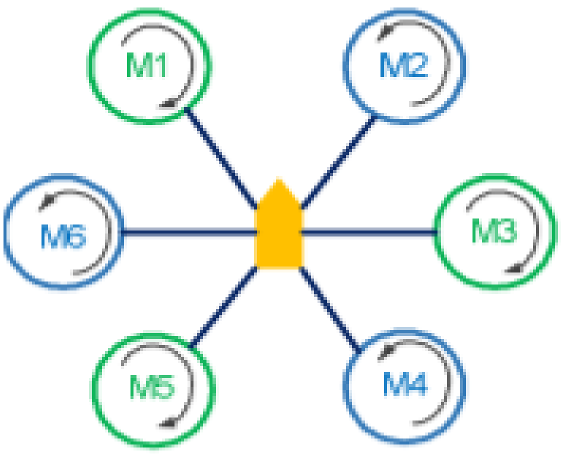

Figure 2.3: Cross- Configuration of hexa-copter [9]

A hexa-copter is an aircraft configured with six rotors, where three rotors rotate in clockwise direction and the others rotate in counterclockwise direction. Figure 2.3 shown the hexa-copter which using cross- configuration. The hexa-copter configuration is combines two large lift propellers, with a constant rotational velocity, with four small control propellers commanded by an autopilot. The UAV designed and developed at Kathmandu University is called as KU-COPTER, which is a multirotor with six propellers (technically called as hexa-copter) which can vertically take-off and land with the purpose to take aerial surveillance and supply of medical aids [9].

Figure 2.4: Assembled Hexa-copter Design [9]

There are many parts in a structure of a hexa-copter. The main part of the hexa-copter is frame which has 6 arms as shown in Figure 2.4. There are many components will be attached on the frame which are battery, four brushless DC motors, controller board, four propellers, and different types of sensors. Therefore, the rigidity and weight of the frame must be prioritized to host all the components above. The motors selected must place same distance from the center on opposite sides to avoid any aerodynamic interaction between propeller blades. There are two types of the configuration normally use in the hexa-copter which are plus and cross configuration.

2.1.3 Comparision between Quadcopter and Hexacopter

Table 2.1 shows the summary for each type of drone by its different specifications. Quadcopter is a drone consists of 4 motors and 4 propellers which can be either plus or cross configuration. Hexa-copter is a drone consists of 6 motors nad 6 propellers which can be either plus or cross configuration. Quadcopter has lower cost and payload but hexa-copter has higher cost and payload.

Table 2.1: Comparison between Quadcopter and Hexa-copter

		Type of Drone	
No	Specifications	Quadcopter	Hexacopter
1.	Number of motors	4	6
2.	Number of propellers	4	6
3.	Type of Configuration	Plus or Cross	Plus or Cross
4.	Cost	Lower	Higher
5.	Payload	Lower	Higher

2.2 Axis of Drone

Axis of Drone is one of the main objectives to be achieved in this thesis where it serves as the parameter of the weight optimization of drone. Literature review of axis of drone design for drone application is discussed in the sections below.

During flying in a desired direction, thrust force is necessary to guide correctly. There is one element used in sensing which is very important for all drones which is the MEMS IMU (inertial measurement unit), which consists of an accelerometer and a gyroscope, both measuring their respective quantities in the drone body frame [9]. Accelerometers help measuring the angle of quadrotor and adjust the revolution per minutes (rpm) of each motor to self-stabilize by itself. Setting of the direction of rotation clockwise of one set of opposite motors and counterclockwise of other set of motors which nullifies the net moment and gyroscopic effects. The pitch and roll orientation motion of the drone can be estimated more accurately when the information from accelerometer and gyroscope are combined.

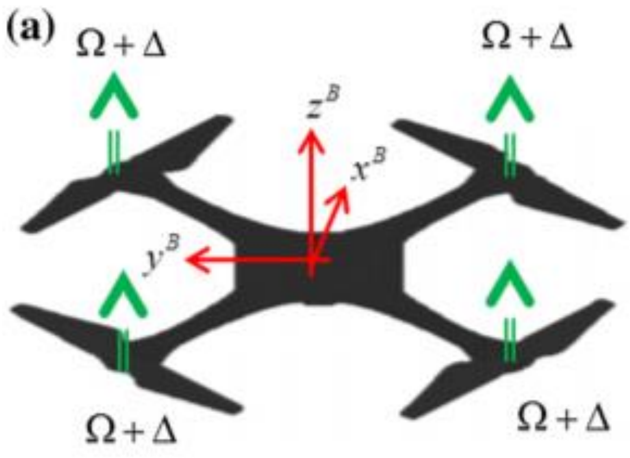

Figure 2.5: 3-axis Quadcopter [10]

Figure 2.5 shown the basic flight mode of 3 axis drone. The 3-axis drone is a drone which can vertically lifting during flight with only a gyroscope, which can only be stabilized by directly commanding the angular velocity.

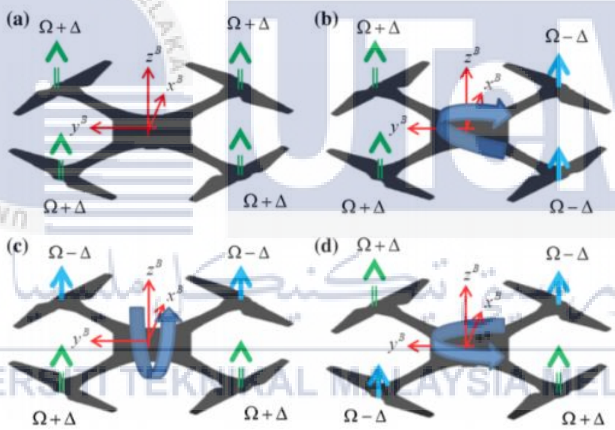

Figure 2.6: 6-axis Quadcopter [10]

Figure 2.6 shown the basic flight mode of 6 axis drone. The 6-axis drone is a drone which can have vertically lift, rolling, pitching, and yawing rotation during flight with a gyroscope and an accelerometer. This helped a user or computing station to control the pitch and roll motions.

2.2.1 Comparision between 3-axis quadcopter and 6-axis quadcopter

Table 2.2 shows the summary for each type of axis of drone by its different specifications. 3 axis of drone will having low cost but lower resistant to altitude displacement. The 6 axis of drone will having high cost and higher resistant to altitude displacment.

Table 2.2: Comparison between 3-axis quadcopter and 6-axis quadcopter

		Type of axis	
No	Specifications	3-axis	6-axis
1.	Cost	Low	High
2.	Resistancy to Altitude Displacement	Low	High

2.3 Design Method

2.3.1 Conventional Design

Conventional engineering design is the design that involves the repeated analysis and modification of an initial concept until a satisfactory design produced [11]. In every stage of the conventional design, properties of the design are evaluated and compared with the specified requirements to evaluate the role of optimization in design and its relationship with traditional methods. Conventional design process does not involve computer simulations of predicted energy performance which has high possibility for leading to a poor performance and high costs operations.

Table 2.3 shows the conventional design process with 5 important stages which are analysis, synthesis, simulation, evaluation and decision. The first stage will start by identifying the design problem and definiing the design goal, functional and technical requirement. Therefore, potential solutions have to start generating and outlining before modelling the expected behaviour of the product. The evaluation will be done by comparing the simulation results with requirements before confimring the validity of solution and meke the final decision.

Table 2.3: Conventional Design Process [11]

No	Stages	Comments
1.	Analysis	Start identifying the design problem, defining the design goal ,functional and technical requirements.
2.	Synthesis	Generating and outlining potential solutions
3.	Simulation	Modelling the expected behaviour of the product
4.	Evaluation	Comparing simulation results with requirements
5.	Decision	Confirming the validity of the solution

2.3.2 Generative Design

Generative approaches are recently becoming more and more applied in a variety of technical fields. By implementing artificial intelligence tools, they can elaborate and propose to a human user a series of plausible solutions for a design problem. More recently, Generative Design has been applied in the mechanical field to pursue performance-driven design [12].Generative Design is a design method that is reliant on the capabilities of contemporary CAD systems [13].By using Generative Design method, several alternative configurations that satisfy a set of imposed design constraints and maximize a goal function passed to the algorithm. The proposed alternatives are the result of an iterative exploration of the related solution space that is guided by an artificial intelligence.

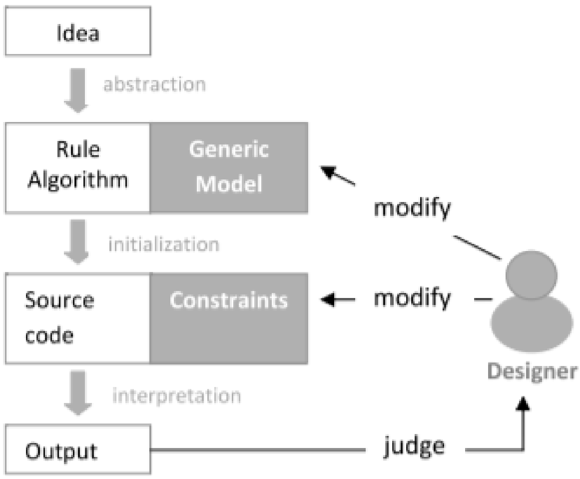

Figure 2.7: Generative Design Process [13]