THE DEVELOPMENT OF FRAMEWORK FOR A LIGHTWEIGHT METALLIC DRONE FRAME USING SELECTIVE LASER MELTING (SLM) 3D PRINTING MACHINE

MUHAMMAD SYAFIQ SYAZWAN BIN ABU ZAKI

M042210038

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

2024

Faculty of Mechanical Technology and Engineering

THE DEVELOPMENT OF FRAMEWORK FOR A LIGHTWEIGHT METALLIC DRONE FRAME USING SELECTIVE LASER MELTING (SLM) 3D PRINTING MACHINE

Muhammad Syafiq Syazwan Bin Abu Zaki

Master of Science in Mechanical Engineering

2024

THE DEVELOPMENT OF FRAMEWORK FOR A LIGHTWEIGHT METALLIC DRONE FRAME USING SELECTIVE LASER MELTING (SLM) 3D PRINTING MACHINE

MUHAMMAD SYAFIQ SYAZWAN BIN ABU ZAKI

A thesis submitted
in fulfillment of the requirements for the degree of Master of Science
in Mechanical Engineering

Faculty of Mechanical Technology and Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2024

DECLARATION

I declare that this thesis entitled “Development of Sturdy Lightweight Drone Frame Printed with Selective Laser Melting Printer” 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 :

Name : Muhammad Syafiq Syazwan Bin Abu Zaki

Date : 1 May 2025

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is sufficient in terms of scope and quality for the award of Master of Science in Mechanical Engineering.

Signature	:	
Supervisor Name	:	Dr Mohd Taufik Bin Taib
Date	:	1 May 2025

DEDICATION

To my beloved parents,

Abu Zaki Bin Romli and Che Liah Binti Ahmad

Thank you for all the support, encouragement, enthusiasm, patience, and willingness.

To my honoured supervisor,

Dr Mohd Taufik Bin Taib, Prof. Madya IR. Dr Mohd Hadzley Bin Abu Bakar and all UTeM lecturers and staff.

To my dearest friends

Thank you for always giving me guidance and persistent help to complete this thesis project.

ABSTRACT

The efficient execution of heavy-duty tasks by drones necessitates a robust frame capable of lifting heavy objects from a stable, elevated position. However, traditional solid materials contribute to excessive weight, accelerating battery deterioration. Moreover, complex designs pose challenges for conventional machining methods. This study aims to design a lightweight and sturdy drone frame using stainless steel via generative design. Strength and stability are evaluated through simulation and experimentation. The proposed solution leverages additive manufacturing, specifically Selective Laser Melting (SLM) 3D printing, with stainless steel powder. To design a drone frame that is suitable for that requirement, first needs to study the machine's behaviour and the mechanical properties of the material. To understand the machine's capability, the experiment that was decided is a surface roughness test by experimenting with the printing orientation of specimens. The specimens were printed using three parameters: the effect of surface area, the effect of height, and the effect of printing angle. Then, the specimens underwent a surface roughness test to determine which printing orientation was the best for manufacturing the drone frame. For the mechanical properties, the experiments that were executed were impact tests and tensile tests. The specimens were drawn first using Autodesk Fusion 360, guided by the American Society for Testing and Materials (ASTM), and fabricated using a Selective Laser Melting (SLM) 3D printing machine. The parameters for these experiments are the material state of the stainless steel powder (virgin and recycled powder), the thickness of the specimens, and the coordination of the specimens on the production bed. After finishing all the physical experiments, the process proceeds to the simulation experiment. First, sketch multiple designs of the drone frame. Those designs that were sketched will be drawn using Autodesk Fusion 360 and undergo a Generative Design process. After that process, the design file was exported to STEP format (.step) for simulation using the Static Structural study in Finite Element Analysis (FEA) within Autodesk Fusion 360. This allowed for the evaluation and selection of the best drone frame design before proceeding to the manufacturing stage. The best design that was selected from the FEA simulation test is manufactured using the Additive Manufacturing method, which is the Selective Laser Melting (SLM) 3D Printing machine using stainless steel powder as the main material. As a result, a sturdy and lightweight drone frame was successfully fabricated by combining innovative design strategies with advanced manufacturing techniques. The feasibility of generating sufficient thrust from the selected brushless motors to lift the frame was also evaluated. This research offers a practical solution to the challenges of weight, strength, and complexity in drone frame construction.

PEMBANGUNAN RANGKA KERJA UNTUK KERANGKA PESAWAT UDARA TANPA PEMANDU (UAV) RINGAN DIBINA DENGAN PENCETAK 3D PELEBURAN LASER TERPILIH

ABSTRAK

Pelaksanaan tugas berat yang cekap oleh dron memerlukan rangka teguh yang mampu mengangkat objek berat dari kedudukan yang stabil dan tinggi. Walau bagaimanapun, bahan pepejal tradisional menyumbang kepada berat berlebihan dan mempercepatkan kemerosotan bateri. Selain itu, reka bentuk yang kompleks menimbulkan cabaran untuk kaedah pemesinan konvensional. Oleh itu, kajian ini bertujuan untuk mereka bentuk rangka dron yang ringan dan kukuh menggunakan keluli tahan karat melalui reka bentuk generatif. Kekuatan dan kestabilan dinilai melalui simulasi dan eksperimen. Penyelesaian yang dicadangkan adalah pembuatan bahan tambahan, khususnya pencetakan 3D Peleburan Laser Terpilih (SLM), dengan menggunakan serbuk keluli tahan karat. Untuk merekabentuk bingkai dron yang sesuai untuk keperluan diatas, terlebih dahulu perlu mengkaji kelakuan mesin dan sifat mekanikal bahan tersebut. Untuk memahami keupayaan mesin, eksperimen yang diputuskan ialah ujian kekasaran permukaan dengan melakukan eksperimen dengan mempelbagaikan orientasi cetakan untuk setiap spesimen. Spesimen dicetak menggunakan tiga jenis parameter: kesan luas permukaan, kesan ketinggian, dan kesan sudut cetakan. Kemudian, spesimen menjalani ujian kekasaran permukaan untuk menentukan orientasi pencetakan yang terbaik untuk menghasilkan bingkai dron. Bagi sifat mekanikal bahan yang dicadangkan, eksperimen yang telah dilaksanakan ialah ujian hentaman dan ujian tegangan. Spesimen dilukis terlebih dahulu menggunakan Autodesk Fusion 360, dipandukan oleh American Society for Testing and Materials (ASTM), dan direka menggunakan mesin pencetak 3D Peleburan Laser Terpilih (SLM). Parameter untuk eksperimen ini ialah keadaan bahan serbuk keluli tahan karat (serbuk dara dan serbuk kitar semula), ketebalan spesimen, dan penyelarasan spesimen pada tapak pembinaan. Selepas selesai semua eksperimen fizikal, proses diteruskan ke eksperimen simulasi. Langkah pertama ialah degan melakarkan lima reka bentuk bingkai dron. Reka bentuk yang dilakar akan dilukis menggunakan Autodesk Fusion 360 dan menjalani proses Reka Bentuk Generatif. Selepas proses itu, proses simulasi menggunakan kajian Tekanan Statik dalam Finite Element Analysis (FEA) dalam perisian Autodesk Fusion 360 untuk memilih hasil reka bentuk bingkai dron yang terbaik lalu meneruskan proses pembuatan. Reka bentuk terbaik yang dipilih daripada ujian simulasi FEA dihasilkan menggunakan kaedah Pembuatan Aditif iaitu mesin Pencetakan 3D Peleburan Laser Terpilih (SLM) dengan menggunakan serbuk keluli tahan karat (dara) sebagai bahan utama. Hasilnya, bingkai dron yang kukuh dan ringan berjaya direka dengan menggabungkan strategi reka bentuk yang inovatif dengan teknik pembuatan termaju. Kebolehlaksanaan menjana tujahan yang mencukupi daripada motor untuk mengangkat bingkai juga dinilai. Penyelidikan ini menawarkan penyelesaian praktikal kepada cabaran berat, kekuatan dan kerumitan dalam pembinaan rangka dron.

ACKNOWLEDGEMENTS

In the Name of Allah, the Most Gracious, the Most Merciful

First and foremost, I want to express my gratitude and thanks to Allah the Almighty, my Creator and Sustainer, for everything that I have received from the beginning of my existence. I'd like to express my gratitude to Universiti Teknikal Malaysia Melaka (UTeM) and Grant no: PJP/2022/FTKMP/S01890 for providing the research environment as well as funding to succeed this project.

Dr. Mohd Taufik Bin Taib, Faculty of Mechanical Technology and Engineering, Universiti Teknikal Malaysia Melaka (UTeM), is my main supervisor, and I am grateful for all of his help, guidance, and inspiration. His unwavering patience in mentoring and offering invaluable insights will be remembered for the rest of my life. Also, thank you to Prof. Madya IR Dr. Mohd Hadzley Bin Abu Bakar, my Co-Supervisor at Universiti Teknikal Malaysia Melaka (UTeM), for his unwavering support throughout my journey.

Last but not least, I want to express my heartfelt appreciation to both of my loving parents, Abu Zaki Bin Romli and Che Liah Binti Ahmad, for their support and encouragement throughout my life. For their tolerance and understanding, I extend my eternal love to Muhammad Aidil Zuhri Bin Abu Zaki, Muhammad Anas Munawwar Bin Abu Zaki, and Nur Sofea Idzlyani Binti Abu Zaki. I'd want to express my gratitude to my family and closest relatives for their unwavering support, love, and prayers. Finally, I'd want to express my gratitude to everyone who has helped, supported, and inspired me to pursue my studies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES