UNIVERSITI TEKNIKAL MALAYSIA MELAKA

IMPROVEMENT DESIGN AND TESTING OF A RAPID ADVANCE FUTURE (RAF) PROSTHETIC LIGHTWEIGHT LEG

FAWZAN HANAFI BIN MOHAMAD FAZDHLI

B091910061

BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (BMMV) WITH HONOURS

2023

Faculty of Mechanical and Manufacturing Engineering Technology

IMPROVEMENT DESIGN AND TESTING OF A RAPID ADVANCE FUTURE (RAF) PROSTHETIC LIGHTWEIGHT LEG

FAWZAN HANAFI BIN MOHAMAD FAZDHLI

BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (BMMV) WITH HONOURS

2023

IMPROVEMENT DESIGN AND TESTING OF A RAPID ADVANCE FUTURE (RAF) PROSTHETIC LIGHTWEIGHT LEG

FAWZAN HANAFI BIN MOHAMAD FAZDHLI

A project report submitted
in fulfilment of the requirements for the degree of
Bachelor of Mechanical Engineering Technology (BMMV) with Honours

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2023

DECLARATION

I declare that this project entitled "IMPROVEMENT DESIGN AND TESTING OF A RAPID ADVANCE FUTURE (RAF) PROSTHETIC LIGHTWEIGHT LEG" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	fawzan
Name	:	FAWZAN HANAFI BIN MOHAMAD FAZDHLI
Date	:	19.1.2023

APPROVAL

I hereby declare that I have checked this thesis, and, in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (BMMV) with Honours.

Signature	:	Rafi
Supervisor Name	:	MOHAMMAD RAFI BIN OMAR
Date	:	19.1.2023

DEDICATION

This project is dedicated to my both parent for their non-stop support, providing with all the need to accomplish this project from the beginning to end. In addition, fellow friends for supporting through ups and down.

ABSTRACT

Prosthetics help people with lifelong disability live independently. In 2015, 80% of the 110 to 190 million individuals living in developing nations were disabled, including 90 million children. RAF prosthetic leg is product that helps disabled people who lost their leg, to move. This study aimed to create a custom-fit prosthetic leg using 3D printing technology and reduce its weight by utilizing FS3300PA Nylon powder material. T-Scan LV is used to achieve cloud data. Computer Aided Design (CAD) and Finite Element Analysis (FEA) software were used to create and optimize the calf cast geometry. Optimization process able to reduce up to 35% of actual mass of the cast. In addition, 3 force are used which is 480.7N, 730.9N, and 961.38N as the simulated loads to compare between old design and latest design. New design able to deliver good structural result with more additional features like improved air circulation, waterproof and lightweight. Design considers 3.0 < s.f < 6.0 safety factor range, where RAF prosthetic leg able to achieve factor of safety of 5.06. Therefore, it is safe for patient to use. Furthermore, leg fabrication utilized SLS (selective laser sintering) technology which employs a strong laser beam to melt and fuse powdered materials like plastic. Throughout optimization and analysis, the product able to improve from previous version and ensure patient achieve comfort and satisfactory.

ABSTRAK

Prostetik membantu orang kurang upaya sepanjang hayat hidup berdikari. Pada 2015, 80% daripada 110 hingga 190 juta individu yang tinggal di negara membangun telah hilang upaya, termasuk 90 juta kanak-kanak. Kaki palsu RAF adalah produk yang membantu orang kurang upaya yang kehilangan kaki mereka, untuk bergerak. Kajian ini bertujuan untuk mencipta kaki palsu tersuai menggunakan teknologi cetakan 3D dan mengurangkan beratnya dengan menggunakan bahan serbuk Nylon FS3300PA. T-Scan LV digunakan untuk mencapai data awan. Perisian Computer Aided Design (CAD) dan Finite Element Analysis (FEA) digunakan untuk mencipta dan mengoptimumkan geometri reka bentuk sarung betis. Proses pengoptimuman mampu mengurangkan sehingga 35% daripada jisim sebenar sarung betis. Selain itu, 3 daya digunakan iaitu 480.7N, 730.9N, dan 961.38N sebagai beban simulasi untuk membandingkan antara reka bentuk lama dan reka bentuk terkini. Reka bentuk baharu mampu memberikan hasil struktur yang baik dengan lebih banyak ciri tambahan seperti peredaran udara yang lebih baik, kalis air dan ringan. Reka bentuk mengambil kira julat faktor keselamatan 3.0 < s.f < 6.0, di mana kaki prostetik RAF mampu mencapai faktor keselamatan 5.06. Oleh itu, ia selamat digunakan oleh pesakit. Tambahan pula, fabrikasi kaki menggunakan teknologi SLS (sintering laser terpilih) yang menggunakan pancaran laser yang kuat untuk mencairkan dan menggabungkan bahan serbuk seperti plastik. Sepanjang pengoptimuman dan analisis, produk ini dapat menambah baik daripada versi sebelumnya dan memastikan pesakit mencapai keselesaan dan kepuasan.

ACKNOWLEDGEMENTS

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

First, always foremost, I want to express my gratitude and praise to Allah the Almighty, my Creator and Sustainer, for all that I have received since the beginning of my life. I want to express my gratitude to Universiti Teknikal Malaysia Melaka (UTeM) for providing the research environment.

Mohammad Rafi Bin Omar, my supervisor, deserves the highest praise for all his help, advice, and inspiration. His unwavering patience in guiding and imparting invaluable insights will be remembered for the rest of his life. This initiative would not have been a success without the ongoing assistance. Also, to my co-supervisor, Dr Muhammad Ilman Hakimi Chua Bin Abdullah for continuing support in completing my journey toward a successive project.

Finally, I want to express my thanks to my family members for their encouragement and for being pillars of strength in all my attempts. I'd also like to express my gratitude to my dear friends for their unwavering support, love, and prayers. Finally, I'd like 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

LIST OF SYMBOLS AND ABBREVIATIONS

RAF	-	Rapid Advance Prosthetic
3D	-	3 Dimensional
IoT	-	Internet of thing
SLS	-	Selective Laser Sintering
PA-12	-	Polymide-12
PA-11	-	Polymide-11
FDM	-	Fused Deposition Modelling
PLA	-	Polylactic acid
PC	-	Polycarbonate
UV	-	Ultraviolet
SLM	-	Selective Laser Melting
MPa	-	Mega Pascal
Mm	-	Millimetre
FS3300PA	-	3D printing material

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Prosthetics are commonly used to assist persons with lifelong disabilities and give them a new chance to live an everyday, independent life. In 2015, the World Health Organization estimated that 80 percent of the 110 to 190 million individuals living in developing countries had a handicap, with more than 90 million children. They also predicted that approximately 25 million people worldwide would require prosthetic or orthotic devices. Currently, there is a great deal of demand (Sundararaj & Subramaniyan, 2020). Prosthetics are made to order for each person, considering their intended function and physical characteristics. Complex geometries are created using a range of 3D printing technologies. The ability to print complicated pieces gives an advantage in "weight-reduction optimisation techniques." As a result, it is becoming increasingly popular in manufacturing healthcare items (Rajput et al., 2021). Therefore, the design and functionality of prosthetic leg should be enhanced, making sure it meets user desires and uses the latest technology.

The tibia and fibula are the lower leg's two long bones. Although they are connected at the knee and ankle, they are two independent bones. The tibia and fibula are joined to the knee joint via a rigid cylinder. This serves as a robust supporting structure that distributes the loads evenly. The foot is the one that follows the design.

The foot has a curved shape that can be difficult and time-consuming to manufacture using traditional methods. The socket is the same way. As a result, the foot and socket can be made using the desired material using 3D printing or other rapid prototyping processes. The rigid cylinder in the prosthetic leg and the four cylindrical rods in the leg can be purchased in typical industrial sizes and machined to the desired geometry or 3D printed with the desired material. The cost is low in both circumstances. Thanks to this streamlined design, the prosthetic limb may be used right away(Sundararaj & Subramaniyan, 2020).

The goal of this study was to fabricate a prosthetic leg using additive manufacturing (3D printing). One of them is SLS 3D printing. SLS (selective laser sintering) is a 3D printing technique that uses a powerful laser beam to melt and fuse small particles layers of powdered materials such as plastic (typically nylon) or metal. After a printed layer is completed, the laser crosses over a powder surface, and the plastic powder is disseminated over. The powder particles melt when the laser passes over this new layer, interfusing with each other and with the last layer. SLS technology comes in handy when printing complex things with exquisite features(*Circular Convolution and Discrete Fourier Transform*, 2014). Polyamide 12 was chosen as the material for the prosthetic leg because it is one of the most used polymeric materials in the process (Sindinger et al., 2020). It can withstand much wear and tear, extending the product's life.

This project will focus on improving Rapid Advance Future (RAF) prosthetic lightweight leg design. Mainly is to reduce its weight and to optimise the air circulation design. The focus is also aimed to improve the user experience when using the RAF application. Improvement will include redesigning the application interface, adding more features like walking time and adding notification alert.

1.2 Problem Statement

The RAF prosthetic leg is product that helps disabled people who lost their leg to move. Improvement design and functionality of the prosthetic leg are crucial for this device to meet user's need. Unfortunately, several problems need to be faced.

Firstly, the problem that needs to be encountered is excessive part removal that can reduce weight to some extent, which also impacts structural strength of the prosthetic (Rajput et al., 2021). Therefore, this study aims to ensure the prosthetic leg equip with lightweight features but has a high durability structure. Secondly, many patients do not have access to these prosthetic devices due to poverty, high prosthetic costs, and technician shortages (Sundararaj & Subramaniyan, 2020). To encounter this problem, the use of low-cost material such as polymide-12 will be applied. Lastly, many low-cost prostheses are incapable of allowing a person to freely walk, run, or sit comfortably on their own (Sundararaj & Subramaniyan, 2020). As a result, the flexibility of the prosthetic leg will be highlighted when conducting this study.

Therefore, this study aims to encounter the all the problem above. This helps to improve product quality.

1.3 Research Objective

1. To improve design of Rapid Advance Future (RAF) prosthetic lightweight leg.
2. To optimize weight of RAF prosthetic leg using topology optimization technique.

3. To fabricate the Rapid Advance Future (RAF) prosthetic lightweight leg by using the 3d printer.

1.4 Scope of Research

The scope of this research are as follows:

1. Optimize use of CATIA and Solidwork to design custom fit prosthetic leg based on patient's measurement.
2. Utilize engineering software, Altair Inspire to optimize weight while maintaining structure integrity.
3. Fabricate the Rapid Advance Future (RAF) prosthetic lightweight leg by using the SLS 3d printer.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, relevant literature for a particular research field is identified, evaluated, and summarised. It looks at knowledge that has been studied or developed before, which is generally known, what emerges, and how the topic is currently being considered. This section will describe the prosthetic leg, the human anatomy involved, prosthetic technology, and the testing required for prosthetic leg design and fabrication.

2.2 K-Chart

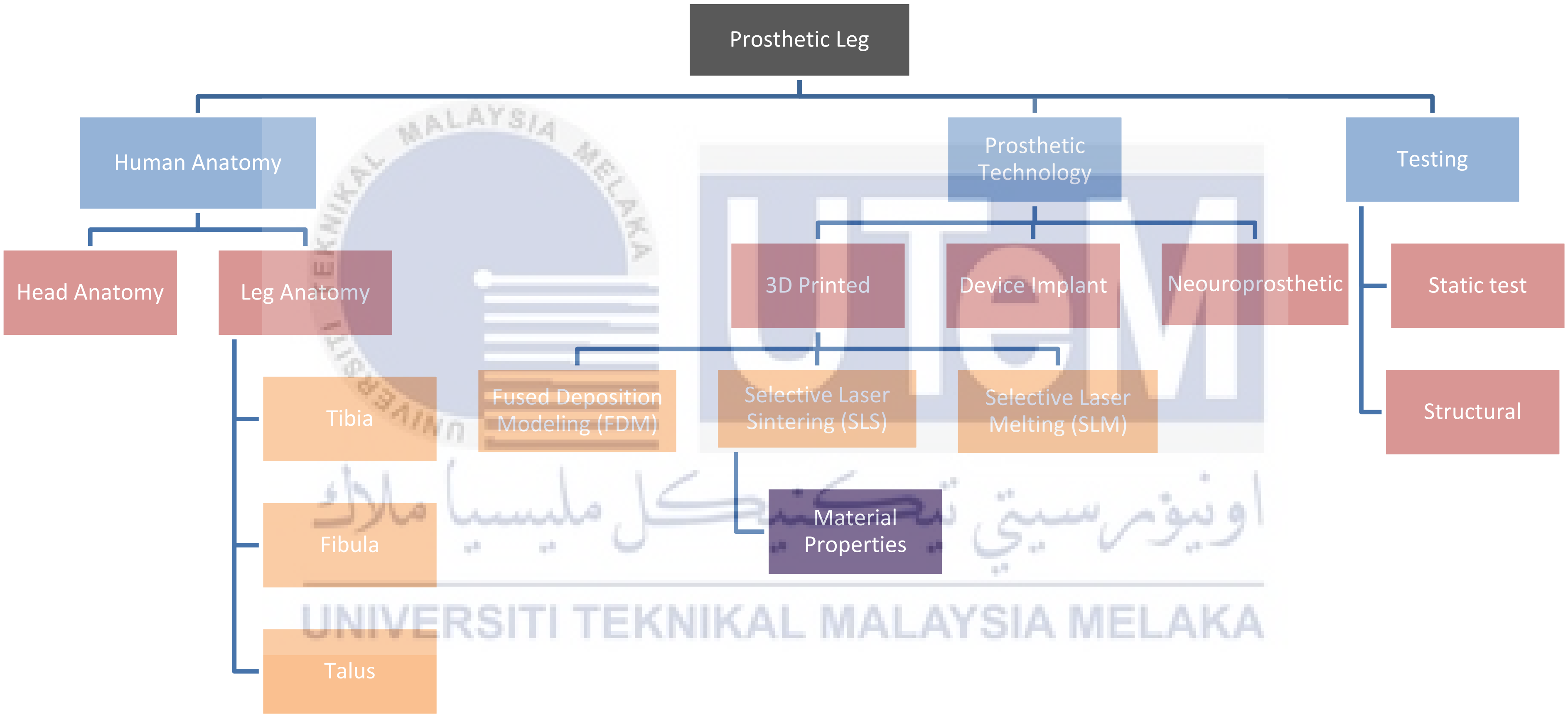

Figure 2.1 K-chart

2.3 Prosthetic Leg

A prosthesis is an artificial device that replaces a missing portion of the human body. The growing prevalence of accidents, vascular illness, congenital disabilities, and other medical issues have necessitated the use of prosthetics (Jeet et al., 2020). The amputee will require prosthetic devices and services for the rest of their life. A prosthesis is an artificial extension that substitutes a missing bodily component, such as a lost upper or lower extremity. It is part of the discipline of biomechatronic, which is the science of merging mechanical devices with human muscle, bone, and neurological systems to help or increase motor control lost due to trauma, sickness, or defect (Paper et al., 2019.)

Figure 2.2 Prosthetic Leg

2.4 Human Anatomy

The study of human anatomy has long been regarded as a foundational component of basic scientific education (Tubbs et al., 2014). Humans are land animals who dwell on the surface of the earth. Our anatomy and physiology are adaptations that allow humans to exist on land, deal with environmental changes, and get the ingredients of life, such as oxygen, water, and nutrition, to maintain cellular processes (*BIOM*2000DE Concepts in Human*

Physiology Course Outline Instructor Contact, 2016). Human anatomy and physiology are regarded as foundational courses in any health-related professional school; they provide a foundation in human form and function and actas a prerequisite for further nursing courses and clinicals (Narnaware & Neumeier, 2021).

2.4.1 Head Anatomy

The head anatomy consists of central skull base. The central skull base is a complicated anatomical area of the head and neck that can be affected by a range of neoplastic, vascular, infectious, inflammatory, and developmental diseases. It acts as a dividing line between extracranial and intracranial areas such as the Sella, cavernous sinuses, and temporal lobes. It also serves as a passageway for several vital veins and nerves. The sphenoid bone's body and larger sphenoid wings and the squamous section and anterior surface of the temporal bone's petrous portion make up the central skull base (Abunimer et al., 2021).

2.4.2 Leg Anatomy

The Leg is divided into four sections. These compartments include muscles, blood vessels, and nerves. Around the knee joint, there are two artery networks: deep and superficial. A superficial network (patellar network - rete patellar) arises between the epidermis and the deep fascia. On the other hand, deep plexus is located near the tibia and femur joint surfaces (genicular anastomosis – rearticulate genus). The branches that branch off from this plexus supply the fibrous and synovial membranes of the knee joint. The descending genicular artery, a branch of the femoral artery, the descending branch of the lateral circumflex femoral artery, the recurrent branch of the anterior tibial artery, superior lateral and medial genicular arteries, inferior lateral and medial genicular arteries, and