UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN AND ANALYSIS OF PASSIVE HIP EXOSKELETON

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor's Degree of Manufacturing Engineering Technology (Product Design) with Honours.

by

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2018

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

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SESI PENGAJIAN: **2018/19**

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APPROVAL

I hereby declare that I have read this dissertation/report and in my opinion this dissertation/report is sufficient in terms of scope and quality as a partial fulfillment of Bachelor Degree of Manufacturing Engineering (Product Design).

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Supervisor Name: Dr. Ismail Bin Abu Shah

ABSTRACT

The external skeletons, exoskeletons, are not a new study area in this high-technology world. Exoskeleton are first invented for the reason of augmenting human strength but then the rehabilitation purposed exoskeletons are also widely developed. In this thesis, a passive hip exoskeleton is designed and analyzed by a series of biomechanics simulations. The design objectives were to reduce the risk of developing work-related musculoskeletal disorder (WMSD) among the industry workers who need to perform manual handling tasks in their daily routine work. This thesis presented a brand new design of three degree of freedoms (DOFs) passive hip exoskeleton. The passive hip exoskeleton introduced in this thesis is quite different with the ordinary exoskeletons since the typical exoskeleton will usually designed for the entire leg or entire body, but the exoskeleton presented in this thesis will only focus on the hip. The reason for design a passive exoskeleton instead of the active one is because the passive exoskeletons have relative lightweight, easy to wear and low cost compare with the active one. This thesis focused on the design and analysis of the passive hip exoskeleton and verifies if the design has a reliable and stability structure. Hence, a series of analysis will undergo to support it. The design of the passive hip exoskeleton drew by using Solidwork software and performance of the exoskeleton model has been checked by the finite element analysis in Solidthinking software according to the applied forced and moment. Lastly, the future recommendation or optimization suggestion is provided for a better design. After undergoing all the analysis needed, the passive hip exoskeleton designed in this thesis is achieved the objectives.

ABSTRAK

Kerangka luaran, exoskeleton, bukan bidang kajian baru dalam dunia teknologi tinggi ini. Exoskeleton mula-mula dicipta untuk meningkatkan kekuatan manusia, kemudian exoskeleton untuk pemulihan juga berkembang secara meluas. Dalam tesis ini, exoskeleton pinggul pasif direka dan dianalisis oleh satu siri simulasi biomekanik. Objektif reka bentuk adalah untuk mengurangkan risiko membangunkan kesakitan muskuloskeletal (WMSD) di kalangan pekerja industri yang perlu melakukan tugas mengangkat manual dalam kerja rutin harian mereka. Tesis ini membentangkan reka bentuk tiga derajat kebebasan (DOFs) exoskeleton pinggul pasif. Eksoskeleton pinggul pasif diperkenalkan dalam tesis ini agak berbeza dengan exoskeleton biasa kerana exoskeleton biasa biasanya akan direka untuk seluruh kaki atau seluruh badan, tetapi exoskeleton yang dibentangkan dalam tesis ini hanya akan menumpukan pada pinggul. Sebab untuk reka bentuk exoskeleton pasif bukannya aktif adalah kerana exoskeleton pasif lebih ringan, mudah dipakai dan kos rendah berbanding dengan yang aktif. Tesis ini memberi tumpuan kepada reka bentuk dan analisis exoskeleton pinggul pasif dan mengesahkan jika reka bentuk mempunyai struktur yang boleh dipercayai dan stabil. Oleh itu, satu siri analisis akan menjalani untuk menyokongnya. Reka bentuk exoskeleton pinggul pasif akan dibuat dengan menggunakan Solidwork dan prestasi model exoskeleton telah diperiksa oleh analisis unsur dengan menggunakan Solidthinking mengikut keberatan dan momen yang digunakan. Terakhirnya, cadangan masa depan atau cadangan penambahbaikan disediakan untuk reka bentuk yang lebih baik. Selepas menjalani semua analisis yang diperlukan, exoskeleton pinggul pasif yang direka dalam tesis ini dapat mencapai matlamat.

DEDICATION

To my beloved family.

ACKNOWLEDGEMENT

This acknowledgement is the ‘finale’ of my thesis in my Bachelor’s degree and also my life as a student. Hence, I would like to take this opportunity to express my thankfulness to the people who helped me during my thesis.

First and foremost, I have to thank my supervisor, Dr. Ismail Bin Abu Shah from Faculty of Engineering Technology, University Technical Malaysia Melaka (UTeM). Without his assistance and dedicated involvement in every step throughout the process, this paper would have never been accomplished. Dr. Ismail helped me come up with the thesis topic and guided me over the whole process. And during the most difficult times when writing this thesis, he gave me the moral support and the freedom I needed to move on. As my lecturer and supervisor, he has taught me more than I could ever give him credit for here.

I would also like to show gratitude to my committee, including Puan Nurul Ain Binti Maidin, Encik Mohd Hidayat Bin Abd Rahman and Encik Muhammad Syafik Bin Jumali for being my major advisor. Those committees were my lecturers of Rapid Manufacturing, Ergonomic and CNC technology subjects. Their teaching style and enthusiasm for the topic made a strong impression on me and I have always carried positive memories of their classes with me. I discussed early versions of the subjects that I mentioned just now with them. They raised many precious points in our discussion and I hope that I have managed to address several of them here. Even though I do not have opportunity to work with them, previously, the impact of their work on my own study is obvious throughout this dissertation.

Getting through my dissertation required more than academic support, and I have many people to thank for listening to and, at times, having to tolerate me over my university life. I cannot begin to express my gratitude and appreciation for their friendship, Chong Peh Han and Grace Ling Kian Hwai have been unwavering in their personal and professional support during my whole university life. We shared the information and help each other over the whole thesis process. Not only that, their selfless help make me can complete my thesis smoothly.

Most importantly, none of this could have happened without my family. I would like to thank my parents for their wise counsel and sympathetic ear. To my elder sister, who always there for me, and give her support unconditionally every time I was ready to give up. This thesis stands as a testament to all your unconditional love and encouragement.

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LIST OF ABBREVIATIONS

ALEX	Active Leg Exoskeleton
BLEEX	Berkeley Lower Extremity Exoskeleton
BOM	Bill of Material
CAD	Computer-Aided Design
DARPA	Defense Advanced Research Projects Agency
DOFs	Degree of Freedoms
DC	Direct current
EHPA	Exoskeleton for Human Performance Augmentation
FEA	Finite Element Analysis
FF	Foot Flat
HO	Heel off
HS	Heel strike
HAA	Hip abduction/adduction
HFE	Hip flexion/extension
HAL	Hybrid assistive limb
LBD	Low back disorder
LEEs	Lower extremity exoskeletons
MLE	Multiple Leaf Exoskeleton
NIOSH	Nasional Institute of Occupational Safety and Health
BNDR	Bending Non-Demand Return
OSHA	Occupational Safety and Health Administration
PLAD	Personal Lifting Assistive Device
ROM	Range of Motion
SLE	Single Leaf Exoskeleton

SCI	Spinal cord injury
TO	Toe off
WMSD	Work-related musculoskeletal disorder

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of study

Exoskeleton is a wearable device that possess the potential for integration into the factories of the future. From table 1.1.1 had shown the classification of exoskeleton and it is shown that there are three applications of exoskeleton which include performance augmentation, rehabilitation and assistance. In the last few decades, engineers around the world were focusing on developing rehabilitation exoskeleton but most of them are restricted to the laboratory environment. In recent year, the focus already shifted to power augmentation and assistance exoskeletons to enhance the power or augment the healthy individuals, soldiers and industries workers. In this thesis, performance augmentation exoskeleton will be focused and the body part to augment is hip. Besides, the passive exoskeleton will be selected because passive exoskeleton is relatively light in weight and not dependence on power sources. The passive hip exoskeleton designed will assists on industries workers who need to lifting and lowering the goods in the daily working life. The main purpose of designing the passive hip exoskeleton is to reduce the forces used when performing manual lifting tasks and then lower down the risk in developing the work-related musculoskeletal disorder (WMSD) among the industries workers.

The Nasional Institute of Occupational Safety and Health (NIOSH) announces issues guidelines and findings for safe manual lifting which are enforced by its parallel agency focused on regulations, the Occupational Safety and Health Administration (OSHA). The lift equation of NIOSH had recommended that the maximum lifting loads for repetitive lifting by healthy workers is 223N (51Ib) [1]. Not only that, manual lifting tasks will involve bending and squatting postures will cause hips to generate a moment due to the weight of the workers of the body superior to the hip and any load being lifted, hence the recommended maximum spinal compression is about 3400N. To prevent toppling forward while lifting a load, the body must generate an equal and opposite moment and when moving superiorly from the hips, there is less mass to support and cause the required restoring moment decrease. Hence, a passive hip exoskeleton could support the worker's hip to avoid toppling forward and perform lifting tasks easily.

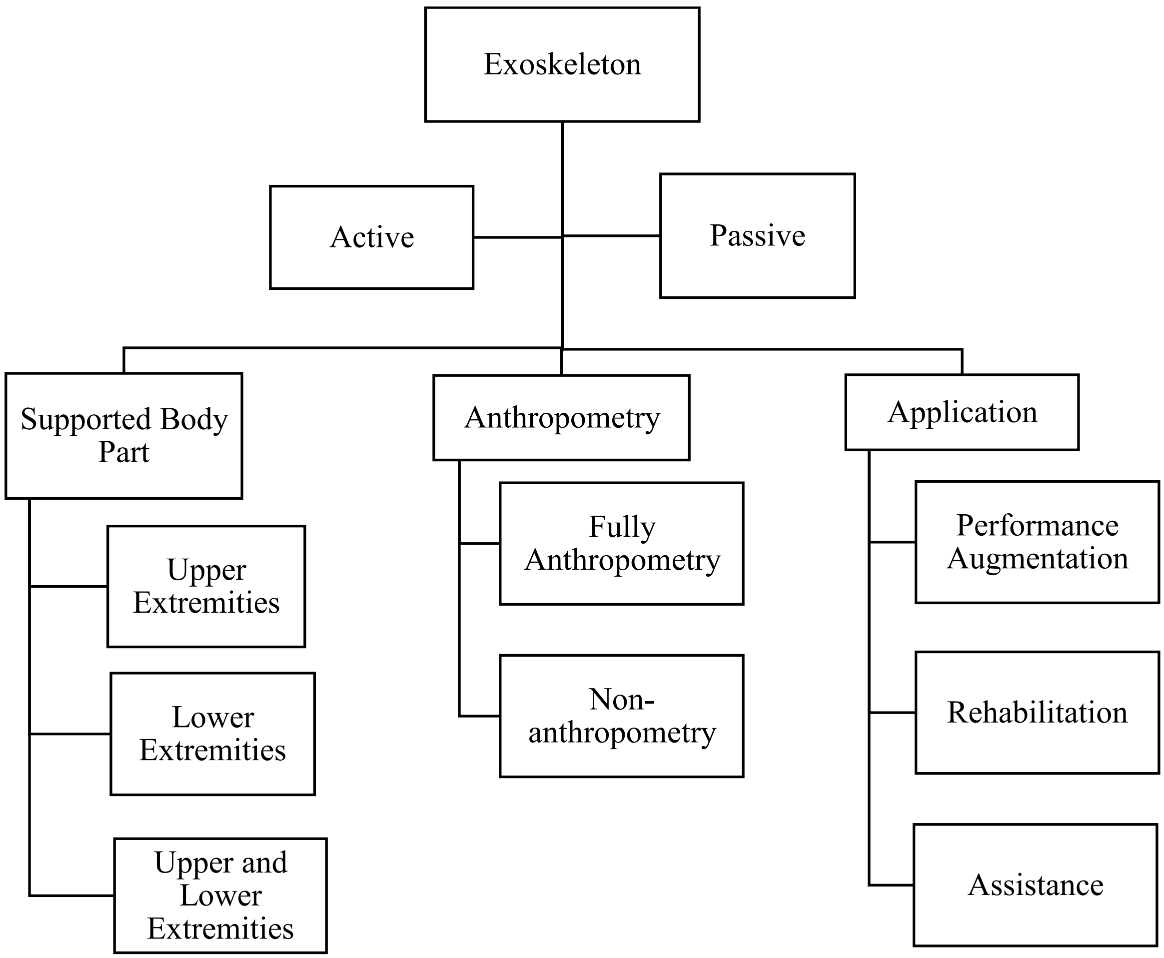

Chart 1.1.1: Classification of Exoskeletons.

1.2 Problem Statement

Low back disorder (LBD) and work-related musculoskeletal disorder (WMSDs) still affect a large number of industry workers although in this automation and mechanization era [2]. LBD and WMSDs are found that often develop on the workers who conduct repetitive material handling and prolonged stooped postures. The field of industry which involve repetitive and sustained tasks like squatting lifting and prolonged stooped posture are agriculture, construction and mining industries. Workers in both developed and developing country used to work with repetitive tasks and awkward postures, hence it is not surprising that many workers throughout the world keep performing tasks over and over again with high risks of developing LBDs and WMSDs.

There are several methods or ways have been proposed to prevent the LBD and WMSDs such as training the worker a proper lifting technique, to adjust the workstation and re-organize the work processes and use the mechanical aid like crane and balancers [3]. However, those methods cannot solve or avoid the development of LBDs and WMSDs effectively. Hence, it is necessary or the reason to design and develop an exoskeleton for solving the not feasible preventive measures that mentioned just now [4]. With the aid of exoskeleton, workers are able to reduce the burden while performing manual lifting in a feasible way.

1.3 Objectives

The objectives for this thesis are:

i. To design and analysis of passive hip exoskeleton and reduce the risk of developing WMSD among industry workers.
ii. To establish a design mechanism of passive hip exoskeleton.
iii. To optimize the design parameters of the mechanism.

1.4 Scope of Study

i. The research object of this thesis is to design and analysis a passive hip exoskeleton to achieve the goal of reducing the risk of industry workers suffering from work-related musculoskeletal disorder (WMSD) due to repetition heavy lifting or other heavy physical workload tasks.
ii. The research focuses on the two dimensional (sagittal plane) hip flexion/extension (HFE) and hip abduction/adduction (HAA).
iii. The model of passive hip exoskeleton will develop by using SOLIDWORK software.
iv. The human model for testing the passive hip exoskeleton will be developed and created by using MAKE HUMAN software and the posture of the human model will be created in BLENDER software.
v. The Finite Element Analysis (FEA) and simulation will be undergoing by using SOLIDTHIKING software to prove that the passive hip exoskeleton designed is achieving the goals of reducing risks of developing WMSD.

3.0 Thesis Outline

This thesis focuses on the design and development of passive hip exoskeleton which could help to protect the industrial workers from suffering for the musculoskeletal disorder (MSD). Chapter 1 presents the introduction of the thesis which includes background study, objectives of the thesis, scope and outline. In background study, a brief explanation of the type of exoskeletons and mechanism were given to give the readers a preliminary concept about exoskeleton.

Chapter 2 is about the literature review about the exoskeleton. There are two separated parts in this chapter, one is the mechanism of the exoskeleton and the other is biomechanical of the hip. The various mechanisms that make the exoskeleton function will present here. Since this thesis title is design and development passive hip exoskeleton, hence the biomechanical of the hip is require to explain here for better understanding. In biomechanical of hip, anatomy, kinematic and kinetic of the hip was presented for giving the reader a deeper understanding how the hip work.

Next, chapter 3 is presented the methodology in design the passive hip exoskeleton. All the method that used in designing passive hip exoskeleton was presented here in detail. This chapter may involve theories, formulas and equations that used to design the exoskeleton. Besides, the methods of data collection that needed in designing the exoskeleton will also be presented.

Chapter 4 will be presented the simulation result and will be discussed in detail for making sure the exoskeleton is safe to use and prove that it achieves the goals of the thesis. In addition, the simulation result of the critical parts of the exoskeleton will be discussed and the further improvement or optimization may have needed according to the result that comes out.

Chapter 5 is the last chapter and a conclusion will be made in this chapter. This chapter will summing-up all the findings and the result of all the topics that discussed in this thesis. Lastly, this chapter will also determine the objectives in this thesis are successfully achieved or not.

3.0 Gantt Chart

No.	Task	WEEK																											
		PSM 1														PSM 2													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	Topic selection	■																											
2.	Journal research	■	■	■	■	■	■	■	■	■	■	■	■				■	■	■	■	■	■	■	■	■	■	■		
3.	Preparation of chapter 1		■	■	■	■	■	■	■																				
4.	Preparation of chapter 2				■	■	■	■	■	■	■	■	■				■	■	■	■	■	■	■	■	■	■	■		
5.	Preparation of chapter 3						■	■	■	■	■	■	■				■												
6.	Submission of progress form and turn-it-in report 1 (Draft)										■	■																	
7.	Submission of combined report, warning letter turn-it-in report 1 (Final)												■	■															
8.	FYP 1 Presentation														■														
9.	Preparation of chapter 4															■	■	■	■	■	■	■	■						
10.	Preparation of chapter 5																						■	■	■				
11.	Submission of progress form and turn-it-in report 2 (Draft)																								■	■			
12.	Submission of combined report, warning letter turn-it-in report 2 (Final)																										■	■	
13.	FYP 2 Presentation																												■

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

Exoskeletons are wearable devices that work in parallel with the human body which can augment a user's physical abilities or increase human strength in carrying heavy objects, jump, squat and walk easier. Exoskeletons can be produced or manufacture by rigid materials such as carbon fibre and metal, or they could be made out of soft and elastic parts. The development of exoskeleton can be traced back to 1965, General Electric (in US) started to develop the Hardiman (Human Augmentation Research and Development Investigation). [5] Hardiman is a full body exoskeleton which designed aim to augment the user's strength to enable them to carry and lift heavy object frequently. Hardiman was found that able to assist user to lift up the load up to 1 500 Ibs (around 682kg). Hardiman was an enormous powered exoskeleton which has a mass of 680kg and it was hydraulically powered (Figure 2.0.1). However, Hardiman presented to have technical problems with the hydro-mechanical servos and balancing problems. Besides, the technical limitation at that time and lack of experience and knowledge impede further improvement of this exoskeleton. Nevertheless, Hardiman also gave engineer some inspiration in a further invention of a exoskeleton and they found that the main problem of Hardiman was the non-portable hydraulic powered supply and also the actuators of the exoskeleton were too heavy and bulky to use. [5]