# CONCEPTUAL DESIGN OF SMART PASSIVE EXOSKELETON FOR MONITORING LOCALIZED PRESSURE AND POSTURAL ANGLE DURING SITTING/STANDING TASKS

This report is submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)



by

**AZMIRUL HYZAIN BIN AHMAD APANDI**

**B051810009**

**940605-06-5203**

FACULTY OF MANUFACTURING ENGINEERING

2022

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

Tajuk: **CONCEPTUAL DESIGN OF SMART PASSIVE EXOSKELETON FOR MONITORING LOCALIZED PRESSURE AND POSTURAL ANGLE DURING SITTING/STANDING TASKS**

Sesi Pengajian: **2021/2022 Semester 1**

Saya **AZMIRUL HYZAIN BIN AHMAD APANDI (94605-06-5203)**

mengaku membenarkan Laporan Projek Sarjana Muda (PSM) ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. *Sila tandakan (√)

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysiasebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)

☐ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/ badan di mana penyelidikan dijalankan)

☑ TIDAK TERHAD

Disahkan oleh:

Alamat Tetap:
06-12 KOMPLEKS KEDIAMAN
KAKITANGAN AWAM (KKKA)
JALAN ANG SENG 4, BRICKFIELDS,
50470, KUALA LUMPUR

Tarikh: 30/6/2022

Cop Rasmi:

DR. ISA BIN HALIM
Lecturer
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka

Tarikh: 30/6/2022

*Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

# DECLARATION

I hereby, declared this report entitled “Conceptual Design of Smart Passive Exoskeleton for Monitoring Localized Pressure and Postural Angle During Sitting/Standing Tasks” is the result of my own research except as cited in references.

Signature : ……

Author’s Name : AZMIRUL HYZAIN BIN AHMAD APANDI

Date : 24 JULY 2022

# APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Bachelor Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

DR. ISA BIN HALIM
*Lecturer*
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka

.....

**(Dr. Isa bin Halim)**

# ABSTRAK

Dalam industri pembuatan, ramai pekerja melaksanakan proses tugasan mereka dalam keadaan berdiri yang terlalu lama. Akibat berdiri terlalu lama, pekerja mengalami ketidakselesaan dan keletihan otot di bahagian bawah badan seperti belakang dan kaki. Kawalan kejuruteraan yang dikaitkan dengan exoskeleton duduk dan berdiri boleh dicadangkan untuk menangani masalah isu ergonomik ini. Exoslekeleton duduk berdiri komersial semasa adalah terhad kerana dia tidak boleh memanjang secara automatik apabila diperlukan disebabkan tapak tempat duduk tidak stabil untuk menstabilkan kedudukan badan untuk kegunaan jangka masa panjang, dan kekurangan sistem maklum balas ergonomik untuk memaklumkan pengguna tentang perubahan dalam kedudukan dari duduk dan berdiri, begitu juga sebaliknya. Objektif kajian ini adalah untuk menentukan keperluan pengguna dan keperluan reka bentuk exoskeleton duduk-berdiri, mencipta dan menilai kesan exoskeleton duduk dan diri yang dihasilkan pada aktiviti otot dan tekanan sentuhan, dan mengintegrasikan exoskeleton duduk dan diri dengan sensor tekanan dalam keadaan berdiri dan duduk secara berselang-seli. Tinjauan dalam talian menggunakan borang Google akan dijalankan untuk mengetahui keperluan pekerja industri berkenaan reka bentuk eksoskeleton duduk dan diri. Sepuluh orang dewasa muda Malaysia yang sihat berumur 21 – 30 tahun akan dipilih untuk mengkaji kesan exoskeleton berdiri duduk pada aktiviti otot dan tekanan di bahagian punggung. Alat elektromiografi (EMG) (Delsys, USA) akan digunakan untuk mendapatkan isyarat EMG pada otot tibialis anterior, vastus lateralis dan gastrocnemius. Sementara itu, Tikar Tekanan Badan (CONFORMat, USA) akan digunakan untuk menganalisis tekanan sentuhan antara punggung dan tempat duduk eksoskeleton. Hasil kajian, rumusan soal selidik mendapati pekerja industri mengalami gangguan muskuloskeletal akibat berdiri lama. Pekerja industri mengemukakan ciri berikut bagi eksoskeleton duduk berdiri masa hadapan: mudah alih, selesa, kos rendah, stabil, boleh laras, ringan, pergerakan kurang terhad, tampan, mudah digunakan, maklum balas

ergonomik boleh mengingatkan mereka supaya mereka boleh Duduk bergantian atau berdiri semasa anda bekerja. Keputusan EMG menunjukkan bahawa exoskeleton duduk berdiri yang dibangunkan dalam kajian ini mampu mengurangkan pengecutan otot sebanyak 75 peratus, yang mencukupi untuk mengurangkan keletihan otot. Berdasarkan keputusan, kajian ini menyimpulkan bahawa exoskeleton duduk-diri yang dibangunkan dalam kajian ini menunjukkan potensi besar dalam mengurangkan ketidakselesaan subjektif dan keletihan otot yang disebabkan oleh berdiri berpanjangan. Faedah penyelidikan ini ialah ia membuat hipotesis bahawa prototaip exoskeleton duduk akan dapat membantu jurutera industri mengurangkan risiko ergonomik yang berkaitan dengan kedudukan berpanjangan di tempat kerja.

# ABSTRACT

In manufacturing industry, many workers perform their task processes in prolonged standing. Due to prolonged standing, workers experienced discomfort and muscle fatigue in the lower body parts such as back and legs. Engineering controls associated with sit-stand exoskeleton can be proposed to resolve these ergonomics issues. The limitations of the current commercial sit-stand exoskeletons are the stand is unable to extend automatically when needed, the base of the stand is not stable to stabilize the body posture for prolonged use, and lack of ergonomics feedback system to alert users in changing positions from sitting and standing, vice-versa. The objectives of this study are to determine users' needs and design requirements of sit-stand exoskeleton, fabricate and evaluate the effects of the fabricated sit-stand exoskeleton on muscle activity and contact pressure, and integrate the sit-stand exoskeleton with a pressure sensor for alternating standing and sitting postures. An online survey using Google form was performed to determine the needs of industrial workers regarding design of the sit-stand exoskeleton. Ten healthy Malaysian young adults aged 21 – 30 years old were selected to study the effects of the sit-stand exoskeleton prototype on the muscle activity and the contact pressure in the buttock. Surface electromyography (EMG) instrument (Delsys, USA) was used to measured and analyzed EMG signals in the tibialis anterior, vastus lateralis, and gastrocnemius muscles. Meanwhile, Body Pressure Mat instrument (CONFORMat, USA) was applied to analyse the contact pressure between the buttock and the exoskeleton seat. As the outcome of the study, the questionnaire survey found that industrial workers suffered from musculoskeletal disorders due to prolonged standing. The industrial workers proposed the following features in the future sit-stand exoskeleton: portable, comfortable, low cost, stable, adjustable, lightweight, low movement restriction, good appearance, easy to use and having ergonomics feedback that can alert them so that they can alternately sit or stand while working. The EMG results showed that the sit-stand exoskeleton developed by this study was able to minimize muscle contraction up to 75 percent which is good

enough for reducing muscle fatigue. Based on the results, this study concluded that the sit-stand exoskeleton developed by this study has shown a great potential to reduce the subjective discomfort and muscle fatigue caused by prolonged standing. The benefit of this study is that study hypothesized that the sit-stand exoskeleton prototype would be able to assist industrial engineers to alleviate the ergonomics risk associated with prolonged standing at workplace.

# DEDICATION

Special dedication my beloved mother, Roslina Binti Abd Malik
my father and my sister, Ir. Ahmad Apandi Bin Lakin and Aini Ardina Binti Ahmad
Apandi for giving me moral support, encouragement and also understandings
Thank You So Much & Love You All Forever

# ACKNOWLEDGEMENT

First, I would want to thank the Bachelor Degree Project Committee, PSM UTeM for organising this project for all final year students. It allows me to learn, comprehend, and implement the data and knowledge I have received over the course of four years of studying. I would also want to thank my supervisor, Dr. Isa bin Halim, who patiently led me throughout the research and provided me with ideas to enhance my project. My Final Year Project would not have done as well or as easily without the supervision. Furthermore, I would like to express my gratitude to all of the staffs, assistant engineers, and students that assisted me, because they were always patient in providing me advice and assistance, which helped me a lot during my data gathering and prototype fabrication. Finally, I would want to express my gratitude to my family, who have always been there for me in every sort of way, as well as to my friends, who have always been there for me and provided me with cooperation and assistance whenever I needed them.

# Table of Contents

# LIST OF FIGURES

# LIST OF TABLES

# CHAPTER 1

# INTRODUCTION

In this first chapter explains about background of study, problem statement, objective, scope of the study, the significance of the study, and the organization of the report. The background of study elaborates how the exoskeleton will benefit to the manufacturing industry. The problem statements define the issue that frequently happens in the manufacturing industry that would encourage to design of the sit-stand exoskeleton. Additionally, the problem statement highlights the limitations of the existing prototype and commercial sit-stand exoskeletons. An objective is a clear statement of the project goal to accomplish design prototype. The scope explains the focus and limitation of the study. The significance of this study shows how the exoskeleton prototype will overcome ergonomics issues on prolonged standing at the manufacturing industry. Lastly, the organization of the report demonstrates how this report is carried out in total.

## 1.1 Background of Study

In manufacturing industry, the workers usually practices the action of prolonged standing for their daily jobs. They did not have a choice because the working area would not allow them to rest in a short period of time because of the hazardous environment and to work right beside the machine. Due to prolonged standing, many workers have taken medical leave because of common health injuries. Thus, this can affect the company production process and their performance. Figure 1.1 shows a worker operating a lathe machine for prolong hours in standing posture.

Figure 1.1: A worker operating a lathe machine in standing posture

Prolonged standing is also common in the service sector: sales clerks, food service employees, salons employees, grocery clerks, customer service representatives, flight attendants, receptionists, and security guards. Standing for most of the working day is bad for the lower limbs; it can damage joints, cause muscular aches, and cause foot issues such as heel spurs and flat feet. The most frequent symptom of operating on feet, and generally the first to begin, is leg pain and exhaustion. Standing for two hours causes EMG signs of muscle exhaustion, severe soreness in the lower back, and edema build-up in the feet. Figure 1.2 shows the muscular aches in the leg due to prolonged standing.

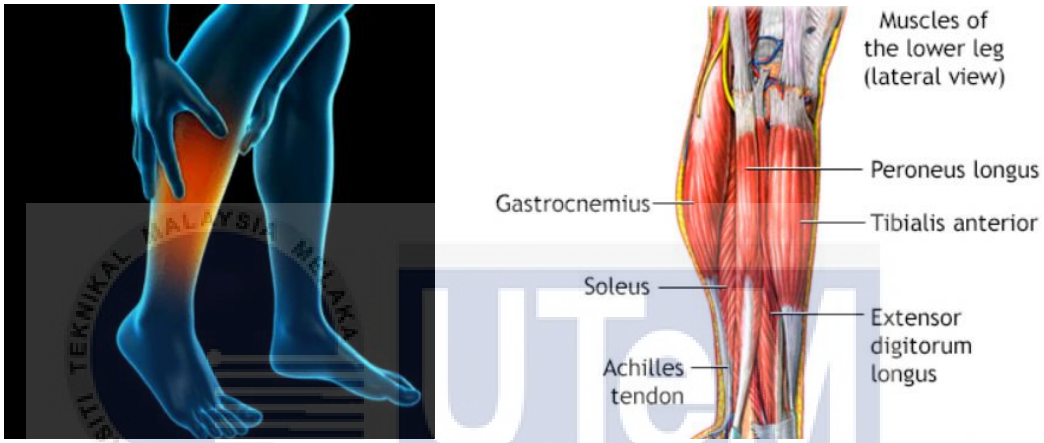



Figure 1.2: Muscular aches in the leg due to prolonged standing



Due to above mentioned issue, the primary goal of this study is to develop a device called passive sit-stand exoskeleton for workers who perform the job in prolonged standing. This passive sit stand exoskeleton can benefit them for preventing muscular aches due to prolonged standing.

## 1.2 Problem Statement

Prolonged standing can cause occupational injuries and physiological discomfort, muscle fatigue, pain and could also contribute to the development of severe health hazards such as Musculoskeletal Disorders (MSDs). MSDs include discomfort and pain in the back, leg, and feet. Figure 1.3 shows discomfort and muscle pain caused by standing for long period of time.

Figure 1.3: Example of discomfort and muscle pain caused by standing for long period of time

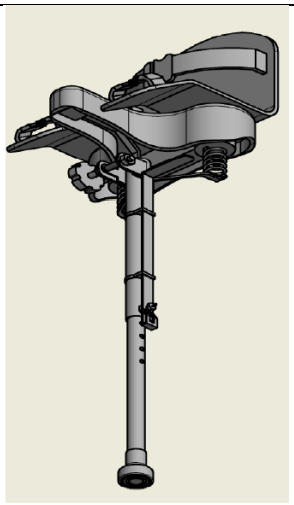
To be specific, this study identified several limitations and constraints of the existing prototype and commercial sit-stand exoskeletons through direct observation and literature review, summarized as follow:



### 1.2.1 Limitations of the design prototype and commercial sit-stand exoskeletons

1. The stand is unable to extend automatically when needed:
   Both existing and commercial exoskeleton can adjust the height by just going down, but it cannot increase the height automatically; thus the user needs to bend to increase the height; this will put the user in the discomfort posture.

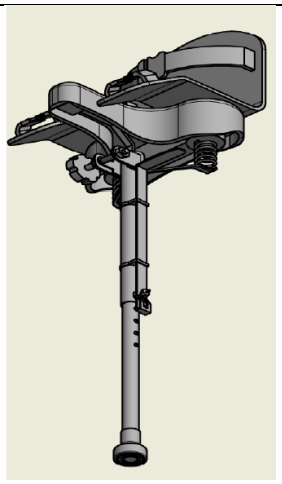
Table 1.1: The stand is unable to extend automatically.

| Existing prototype of sit-stand exoskeleton | Commercial sit-stand exoskeleton |
|---|---|
|  Solehin, 2021 |  Source: www.noonee.com |

2. The base of the stand is not stable to stabilize the body posture for prolonged use: The bottom platform in the existing exoskeleton is too small same goes with the commercial exoskeleton, but the commercial has two small bottom platforms. When the base is small, it can discomfort the user because it is not stable; thus the user needs to use their leg to steady their position when used. Also, a small base has the potential to tilt backwards, and this would lead the user to fall backward.



Table 1.2: The base of the stand is not stable.

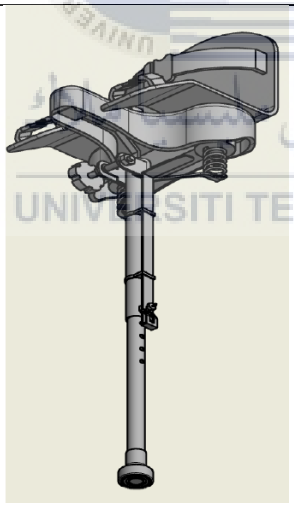
| Existing prototype of sit-stand exoskeleton | Commercial sit-stand exoskeleton |
|---|---|
|  Solehin, 2021 |  Source: www.lexbyastride.com |

### 1.2.2 Lacking of ergonomics feedback system to alert users in changing positions from sitting and standing, vice-versa.

Abundant published literature highlighted that ergonomics interventions using a wearable sit-stand exoskeleton are helpful to minimize muscle fatigue associated with prolonged standing. However, far too little attention has been paid to studying and visualizing the trend/ pattern of data such as force and contact pressure in contact areas such as buttock and feet. Yet, information of force, contact pressure, and time workers start to feel discomfort/ numbness (onset of fatigue) is still unknown.

There are commercial products and prototypes of wearable sit-stand exoskeleton developed by manufacturers and past researchers; however, an exoskeleton that can alert the users (workers) to alternate sit/stand based on quantitative data (postural angle, contact pressure, and time) requires a further study.

Table 1.3: Lack of ergonomic feedback.

| **Existing prototype of sit-stand exoskeleton** | **Commercial sit-stand exoskeleton** |
|---|---|
|  |  |
| Solehin, 2021 | Source: www.archelis.com |

## 1.3 Objectives

a) To determine users' needs and design requirements of sit-stand exoskeleton from Malaysian industrial workers.

b) To evaluate the effects of the fabricated sit-stand exoskeleton on muscle activity and contact pressure of the users.

c) To integrate the sit-stand exoskeleton with pressure and postural angle sensors for a conceptual smart system of alternating standing and sitting postures.

### 1.3.1 Relationship between Problem Statement and Objective

A problem statement is a statement of a current issue or a flaw that needs to be repaired and improves. In design 1, the stand is unable to extend automatically, the user needs to bend to increase the height; this will put the user in the discomfort posture. Design 2, the base of the stand is not stable, it can discomfort the user because it is not stable; thus the users' needs to use their leg to steady their position when used. Design 3, it lack of ergonomics feedback, this is a feature must have because it can inform the worker of what positios there in. An objective is a clear statement of the project goal to accomplish design prototype. The first objective is to determine user needs, where is this study a survey would be conducted and evaluate the feedback. The second objective is to evaluate the fabricated sit-stand exoskeleton, where in this study an exoskeleton is being design and fabricated base on collected feedback. The third objective is to integrate the exoskeleton with pressure sensor, where in this study the product and its features is being testes where it would meet user expectation. Table 1.4 shows the relationship of problem statement and objective.