UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN OF WEARABLE SIT-STAND STOOL FOR PROLONGED STANDING JOBS

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

by

MOHD RIDZMAN IKHZA BIN ZAKARIA

B051610094

940509-02-5949

FACULTY OF MANUFACTURING ENGINEERING

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BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

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Alamat Tetap:

162 LORONG CENGAL UTAMA 1/5
TAMAN CENGAL UTAMA, AMPANGAN
70400 SEREMBAN, N. SEMBILAN

Tarikh: 21 JULY 2020

Cop Rasmi:

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

Tarikh: 10/8/2020

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DECLARATION

I hereby, declared this report entitled "Design of Wearable Sit-Stand Stool for Prolonged Standing Jobs" is the results of my own research except as cited in the reference.

Signature : .....

Author's Name : MOHD RIDZMAN IKHZA BIN ZAKARIA

Date : 21 JULY 2020

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons.). The members of the supervisory committee are as follow:

Isa Halim

.....

(Dr. Isa bin Halim)

ABSTRAK

Pada masa kini, pekerja yang bekerja di sektor perkilangan sering menghadapi sakit belakang oleh kerana berdiri terlalu lama ketika bekerja. Bekerja sambil berdiri boleh menyebabkan keletihan dan menjejaskan kesihatan dan produktiviti bekerja. Oleh sebab itu, projek ini telah dijalankan untuk merekabentuk Wearable Sit-Stand Stool (W3S) untuk pekerjaan yang memerlukan posisi berdiri yang lama ketika bekerja. W3S membenarkan penggunanya berjalan bersama sokongan tempat duduk, tanpa mengganggu ruang di tempat kerja, pada masa yang sama dapat mengelakkan dari postur badan membongkok. Antara objektif utama projek ini adalah untuk mengenalpasti reka bentuk yang sesuai dengan W3S, menganalisa spesifikasi teknikal untuk W3S dan untuk menghasilkan prototaip tahap sederhana. Kajian soal selidik dan Pembahagian Fungsi Kualiti *(QFD)* telah digunakan untuk mengenalpasti reka bentuk yang memenuhi kehendak pengguna. Seterusnya, empat konsep reka bentuk telah dihasilkan dan kesemua reka bentuk telah melalui proses konsep saringan Pugh dan konsep pemarkahan. Kedua-dua proses ini adalah untuk menilai kesemua konsep reka bentuk lalu menghasilkan satu konsep yang terbaik. Jenis bahan yang digunakan untuk W3S telah dipilih melalui pemilihan bahan di mana ia mengunakan proses keperluan reka bentuk, konsep saringan dan konsep pemarkahan. Seterusnya, Pemasangan Reka Bentuk *(DFA)* telah dijalankan untuk mengurangkan kos keseluruhan produk. Tambahan lagi, analisis seperti analisis statik dan analisis tegasan bersama penyelakuan manikin telah dibuat terhadap W3S untuk menentukan kondisi yang terbaik untuk digunapakai oleh pengguna. Setelah kesemua analisis dilaksanakan, prototaip tahap sederhana telah dihasilkan dan prototaip tersebut mempunyai kelebihan seperti panjang boleh laras, sudut kecondongan boleh laras dan kedudukan tempat duduk boleh laras. Dari segi kelestarian pula, W3S menggunakan bahan yang boleh dikitar semula dan ia juga menggunakan komponen dan bahan yang sedikit berbanding konsep reka bentuk yang lain. Oleh sebab itu, kesan pembikinan W3S terhadap alam sekitar adalah rendah.

ABSTRACT

Nowadays, people that working in the manufacturing field are prone to have lower back pain due to working in standing posture for prolonged time. Working in a standing position for many hours is so much tiring and it will directly affect worker's health and work productivity. In order to solve this problem, this project has been conducted to design a Wearable Sit-Stand Stool (W3S) for prolonged standing jobs. W3S allows the users to walk together with the sitting support while wearing it, without obstructing the workspace, at the same time avoiding strenuous postures such as bending. The main objectives of this project are to determine the design requirement of W3S, analyze technical specifications of W3S and to fabricate a medium-fidelity prototype of W3S. In order to achieve these objectives, several methods have been conducted. Questionnaire survey and Quality Function Deployment (QFD) has been developed to determine the design requirement from the customer. Next, four conceptual design was produced based on the design requirement and all the design were going through Pugh concept screening and concept scoring. The material for W3S was chosen based on the method of material selection, which consist of design requirement, concept screening and concept scoring. Next, Design for Assembly has been conducted to reduce assembly time and assembly cost which leads to lower cost of product. Furthermore, a lot of analysis such as static analysis and stress analysis were conducted to W3S to determine the best condition of W3S to the user. After conducting all of the analysis, medium-fidelity prototype has been fabricated and the prototype has additional features like adjustable length, adjustable angle inclination and adjustable seating position. In term of sustainability, material used for the prototype can be recycled and it also used lower amount of material and component compare to other concepts of design. Therefore, the impact of fabrication W3S towards environment are low.

DEDICATION

I would like to dedicate this project to my loving family, my project's supervisor, lecturers and friends that always support and motivate me in completion of this project and report.

ACKNOWLEDGEMENT

First and foremost, to complete my project, I had to ask for the help and guidance of a respected supervisor, who deserves my greatest gratitude. I would like to show my gratitude to Dr Isa bin Halim, for great mentoring and valuable guidance and advice. He inspired me greatly to work in this project. His willingness to motivate me contributed tremendously to my project. I also would like to thank him for showing me some examples related to the topic of our project.

Besides, an honourable mention goes to my families for their understanding and support in completing this project. Without their help for particular, I would face many difficulties and obstacles while doing this project.

Furthermore, I would like to give special thanks to my beloved friends for motivating and supporting me throughout completing this project. They had given me a lot of suggestion and comment regarding my project. Thanks for the great friendship.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

W3S	-	Wearable Sit-Stand Stool
QFD	-	Quality Function Deployment
HOQ	-	House of Quality
CAD	-	Computer Aided Design
DFA	-	Design for Assembly
WELL	-	Wearable Exoskeleton Lower Limb
CFRP	-	Carbon Fiber Reinforced Polymer

LIST OF SYMBOLS

°	-	Degree
RM	-	Ringgit Malaysia
cm	-	Centimeter
%	-	Percentage
kg	-	Kilogram
Nmin	-	Theoretical part count
tma	-	Assembly time (sec)
ta	-	Lowest assembly time (sec)
Ema	-	Manual Assembly Efficiency
Σm	-	Summation of moment
M	-	Moment
m	-	Meter
N	-	Newton
N.m	-	Newton meter
€	-	Europe pound
$	-	United State dollar
e	-	Exponential

CHAPTER 1

INTRODUCTION

Chapter 1 covers the background of the study, problem statement, objectives, scope, the importance of study and organization of the report. Background of the study explains how this product is important toward manufacturing industry and product characteristics. Problem statement shows on problem in the industry that leads to the idea of this project. Next, objectives show the overall goal of this project, whereas scopes show the limitation and method used to produce this project. Importance of study shows how this prototype will solve ergonomics issues related to prolonged standing in industries. Finally, organization of report shows how this report is conducted in overall.

1.1 Background of Study

In the manufacturing industry, the company expects factory workers to sustain efficacy in order to maximize company's productivity. Consequently, the workers are exposed to cumulative trauma injuries depending on the type of work and frequency of activities. A lot of fabrication processes such as conventional milling, turning, welding and drilling require workers to perform in standing position for hours. When workers carry out specific tasks such as lifting heavy equipment, reaching for tools or pushing and pulling huge loads, standing is the best working position. This is because those tasks require frequent movements and a large degree of freedom to move. It is nearly impossible to perform those tasks and processes in a sitting position.

Waters et al. (2014) stated that the effect of continuous standing at work which is more than 4 hours would increase the risk of lower back pain, cardiovascular problems and pregnancy outcomes. Figure 1.1 below shows the part of body which prone to lower back pain. The red color on the body from the figure below shows the position where lower back pain mostly occurs. As stated by Manchikanti et al. (2014), lower back pain causes include heavy lifting, pulling or pushing heavy load and continuous walking or standing. Lee et al. (2017) showed that 14 out of 20 participants are having lower back discomfort after 2 hours of standing.

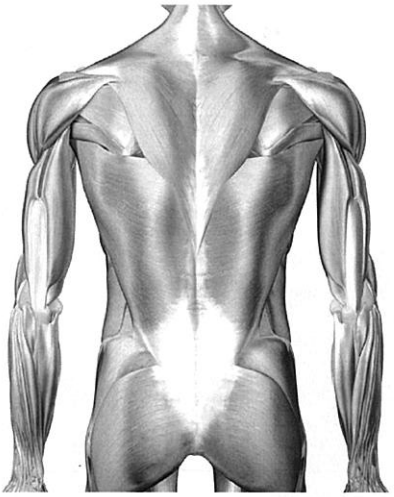

Figure 1.1: Part of body where lower back pain mostly occurs. (Source: "Bauerfeind Medical", 2019)

In recognition to overcome the abovementioned issue, a piece of equipment that can help workers to gradually rest their lower limbs in sitting position from prolonged standing is a necessity. The main goal of this project is to fabricate a medium-fidelity prototype of Wearable Sit-Stand Stool for workers exposed to the jobs that require to stand in a long period of working hours in the manufacturing industry or service industry. This wearable stool allows the users to walk together with the sitting support while wearing it, without obstructing the workspace, at the same time avoiding strenuous postures such as bending. Moreover, this prototype will be equipped with features to enable the user to adjust their best sitting position, inclination angle and adjustable length.

1.2 Problem Statement

Working in a stationary standing position for many hours is so much tiring and it will directly affect worker's health. This study is proven by Antle et al. (2018) which stated that workers that perform a continuous and stationary standing during working hours would have a high chance of having body discomfort and blood pooling in their feet if compared to sitting position. This means that the blood may not flow effectively, which leads to varicose veins on legs. Varicose vein is a large swollen, twisty purple vein that looks like tree branches often on the backside of knee, Lamotte (2018). Figure 1.2 below shows the difference between normal vein and varicose vein on leg.

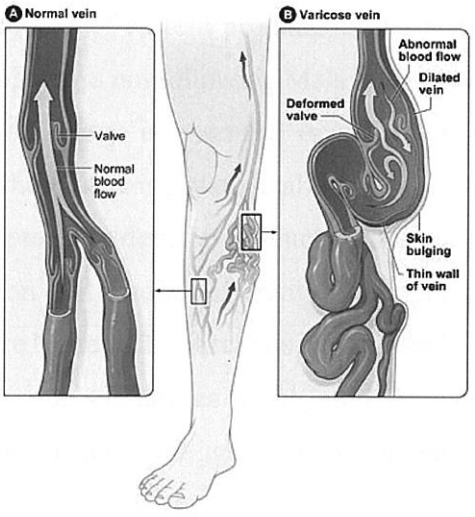

Figure 1.2: The difference between normal vein and varicose vein on leg. (Source: Brazier, 2017)

The symptoms for varicose vein are veins become dark purple or blue in color and painful sign of burning, throbbing, muscle cramping and swelling in lower legs. Figure 1.3 below shows the symptom of varicose vein.

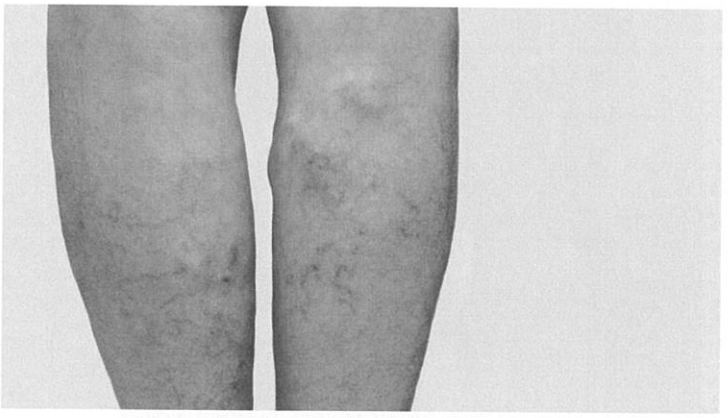

Figure 1.3: The symptom of varicose vein. (Source: LaMotte, 2018)

Size of product plays an important role in achieving comfort, health, safety and productivity from the user. The size of current products in the market that have the same function as Wearable Sit-Stand Stool is not following Malaysian Anthropometry. According to Singh et al. (2015), anthropometry is essential in design industry, apparel design, architecture and ergonomics where utilizing statistical data about the distribution of body dimension in the population are used to develop product. Different lifestyles, nutrition and ethnic composition of population will lead to different in distribution of body dimensions. Examples of current products are Nonee, Lex, Archelis and Ofrees (Table 2.1). Most of these products were fabricated on Europe's countries which obey the European anthropometry. Therefore, the size of the products is mostly bigger and not convenient for Malaysian users.

Also, the design of wearable chair in the market are mostly bulky. This will take up a lot of working space and restrict the user from moving freely. This kind of product is not suitable for working in the manufacturing industry. The ability to move freely during working in manufacturing industry is essential to ensure workers comfortable, able to loosen up and flex the body. When the comfort increase, the performance of workers will increase, thus lead to an increase in productivity of the company. Figure 1.4 below shows a surgeon equipped with wearable chair from Archelis during surgery.

Figure 1.4: Design of wearable-chair from Archelis. (Source: "Archelis – Wearable Chair", 2015)

Besides that, the price of the wearable-chair available in the market is not reasonable with the design, functionality and accessories provided to the customer. The price of the product from Ofrees is RM 3 437 while Nonee is RM 17 257 (Table 2.1). These products are costly and the price is not relevant to the simple function and design of the product. Figure 1.5 below shows the design of wearable-chair from Ofrees.

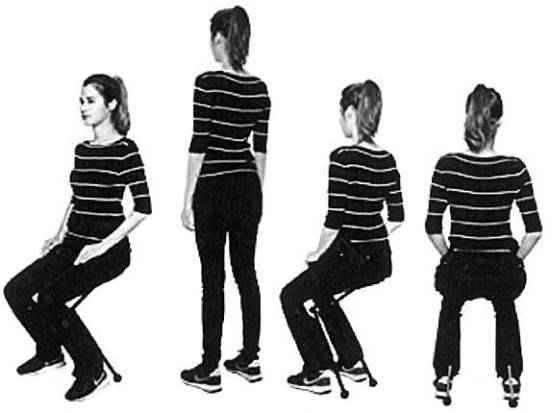

Figure 1.5: Design of wearable-chair from Ofrees. (Source: "Ofrees: Wearable Chairs In the World." 2015)

Table 1.1 below show type of wearable-chair included with the price of the product in the current market.

Table 1.1: Type of wearable-chair with the price of the product.

Wearable-chair	Prices
Nonee	RM 17 257
LEX	RM 1668 – RM 6684
Archelis	RM 11 362
Ofrees	RM 3 437

1.3 Objectives

The objectives of this project are as follow:

(a) To determine the design requirements of wearable sit-stand stool from the workers who expose to prolonged standing jobs in industry.

(b) To analyze the technical specification of the proposed wearable sit-stand stool based on design requirements from the workers.

(c) To fabricate a medium-fidelity prototype of wearable sit-stand stool for workers who exposed to jobs that require standing in a long period of working hours.

1.4 Scopes

The scopes of research are as follows:

(a) Design Wearable Sit-Stand Stool according to Malaysian Anthropometry which based on 300 respondents ranging from the age of 16 to 24 years.

(b) Research on which material suits the best for the overall body of the product. In this research, material selection will be conducted by using screening and scoring method.