DEVELOPMENT OF SMART MODULAR LOWER BODY SUPPORT FOR PROLONGED STANDING

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MASTER OF MANUFACTURING ENGINEERING (INDUSTRIAL ENGINEERING)

2024

FACULTY OF INDUSTRIAL AND MANUFACTURING TECHNOLOGY AND ENGINEERING

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RAJAMUNIRANT A/L KANDASAMY

A thesis submitted
in fulfillment of the requirements for the master of
Master of Manufacturing Engineering (Industrial Engineering)

Faculty of Industrial and Manufacturing Engineering Technology and Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2024

DECLARATION

I declare that this report entitled "Development of Smart Modular Lower Body Support for Prolonged Standing" is the result of my own research except as cited in reference. The thesis has not been accepted for any master and is not concurrently submitted in candidature of any master.

Signature : ……………………………………

Name : Rajamunirant a/l Kandasamy

Date :

APPROVAL

I hereby declare that I have read this report and in my opinion this report is sufficient in terms of scope and quality for the award of Master of Manufacturing Engineering (Industrial Engineering)

Signature : ……………………………………..

Supervisor Name : ……………………………………..

Date : ……………………………………..

DEDICATION

This report is dedicated to my beloved family, friend and my lecturers.

ABSTRACT

Musculoskeletal diseases (MSD) remain a major source of threat for industry workers. A good understanding and handling musculoskeletal health in the workplace establish a secure and effective working environment. Workers in industry are more likely to have MSD disease in the workplace due to overexertion from manually operating machinery. In this project a metal fabrication company which uses a large number of welders requested to carry out a study and find solution on MSD faced by metal inert gas (MIG) welders. The welders were influenced by prolonged standing when they carried out their daily task which leads to MSD. To overcome the MSD during work, the welders took a long break in interval for recovery which leads the increase of cycle time in producing a product. The aim of this research is to improvise current Modular Lower Body Support in the market which lack of height adjustability and lack of sensor to detect poor bending movements and prolonged sitting. The objectives of this study were to analyze the user's requirements, technical specifications and ergonomics considerations for developing the Smart Modular Lower Body Support, designing and developing the Smart Modular Lower Body Support and carry out evaluation on the functionality and usability for the Smart Modular Lower Body Support. The current Smart Modular Lower Body is not similar to the other Modular Lower Body Support in the market. The Smart Modular Lower Body Support is a portable product which can be located in any flat desired location. The height of the lower body support is adjustable, solve the height issue of the welders in the industry and well-integrated with Internet of Things (IoT) monitoring system required by the industry. This Smart Modular Lower Body Support is equipped with 2 types of sensors which are load cells and ultrasonic sensors, play a crucial role in identifying the load exerted by the welders on the lower body support and detects the over bending movement of the welders when they carry out their daily task. The IoT system was build up with a notification system connected to cellular phone software, email notification and alarming electronic product such as buzzer and LED. To develop the Smart Modular Lower Body Support, technical data, user's requirements, ergonomics and work space specifications had been collected at the workplace. House of Quality (HoQ) had been carried out to reflect welder's idea on the product to be developed. The data that had been gathered were used to design a lower body support using SolidWorks software and been tested with Finite Element Analysis (FEA) to understand how the product behave under various physical condition. The best design had been chosen and fabricated from the analysis of (FEA), (HoQ) and Pugh Matrix Analysis (PMA). The fabricated lower body support had been fixed with a few mechanical parts and electrical components. IoT system had been set up with parameter for internal testing. Finally, the Smart Modular Lower Body Support had been tested in the fabrication industry for evaluation on the functionality and usability. As a result, the cycle time of the welding process had been reduced, MIG welders are free from MSD and the welders can use the Smart Modular Lower Body Support continuously without prolong standing issue. A questionnaire had been carried out with 21 respondents on the usability testing of the Smart Modular Lower Body Support and the usability testing gained a score of 51.31 which stand in the grade of "D" with the acceptability of "OK".

PEMBANGUNAN SOKONGAN BADAN BAWAH MODULAR PINTAR UNTUK BERDIRI BERPANJANGAN

ABSTRAK

Gangguan otot berangka kekal (MSD) sebagai ancaman utama bagi pekerja industri. Adalah penting untuk memahami dan mengendalikan kesihatan otot berangka di tempat kerja untuk mewujudkan persekitaran kerja yang selamat dan cekap. Pekerja industri berisiko mengalami gangguan otot berangka MSD disebabkan oleh penggunaan tenaga yang berlebihan ketika mengendali mesin secara manual. Dalam projek ini, sebuah industri fabrikasi yang menggunakan banyak pengimpal gas inert logam (MIG) meminta untuk menjalankan kajian dan mencari solusi terhadap masalah gangguan otot berangka MSD yang dihadapi oleh pengimpal. Pekerja kimpalan terpengaruh dengan posisi berdiri yang lama dalam menjalankan tugasan harian mengakibatkan kepada gangguan otot berangka MSD. Untuk mengatasi gangguan otot berangka MSD, pengimpal rehat untuk jangka masa panjang ketika berkerja bagi pemulihan sakit yang mengakibatkan peningkatan dalam kitaran masa dalam penghasilan produk. Tujuan kajian ini adalah untuk penambahbaikan Sokongan Bawah Badan Modular yang kini digunakan mempunyai kekurangan daripada aspek kebolehlarasan ketinggian dan deria untuk mengesan pergerakan postur badan yang tidak neutral dan posisi berdiri yang lama. Kajian ini bertujuan untuk menganalisis keperluan pengguna, spesifikasi teknikal dan pertimbangan ergonomik untuk membangunkan Sokongan Bawah Badan Modular Pintar, mereka bentuk dan membangunkan Sokongan Bawah Badan Modular Pintar dan penilaian kefungsian dan kebolehgunaan Sokongan Bawah Badan Pintar. Sokongan Bawah Badan Modular Pintar terkini tidak sama seperti sokongan bawah badan di pasaran. Sokongan Bawah Bawah Badan Modular Pintar adalah produk mudah alih dan boleh digunakan di mana-mana lokasi rata. Ketinggiannya boleh dilaras dan menyelesaikan isu ketinggian pengimpal dan disepadukan dengan sistem pemantauan Internet Pelbagai Benda (IoT) yang diperlukan oleh industri. Sokongan Bawah Badan Modular Pintar ini dilengkapi dengan 2 jenis penderia iaitu sel beban dan penderia ultrasonik yang memainkan peranan penting dalam mengenal pasti beban yang dikenakan oleh pengimpal pada sokongan bawah badan dan mengesan pergerakan postur badan yang tidak neutral pengimpal ketika menjalankan tugas harian. Sistem pemantauan Internet Pelbagai Benda dibina dengan sistem notifikasi berhubungan melalui perisian telefon selular, notifikasi e-mel dan produk elektronik seperti buzzer dan LED. Untuk membangunkan Sokongan Bawah Badan Modular Pintar, spesifikasi teknikal, keperluan pengguna, ergonomik dan ruang kerja telah diambil kira. Analisa rumah kualiti (HoQ) telah dijalankan untuk mendapatkan idea pengimpal untuk membina produk. Data yang telah dikumpul digunakan untuk mereka sokongan bawah badan menggunakan perisian “SolidWorks” dan diuji dengan kaedah unsur terhingga (FEA) untuk memahami bagaimana produk berkelakuan di bawah pelbagai keadaan fizikal. Reka bentuk yang terbaik telah dipilih dan direka melalui analisa (FEA), (HoQ) dan Matriks Pugh (PMA). Sokongan bawah badan yang telah dibangunkan telah dipasang dengan beberapa barang mekanikal dan elektrik. Sistem pemantauan Internet Pelbagai Benda telah diaplikasi dengan parameter untuk ujian dalaman. Akhirnya, Sokongan Bawah Badan Modular Pintar telah diuji dalam industri fabrikasi untuk penilaian kefungsian dan kebolehgunaan. Kesimpulanya, kitaran masa telah dikurangakan, pengimpal bebas daripada gangguan otot berangka dan pengimpal boleh menggunakkan Sokongan Badan Bawah Modular Pintar secara berterusan tanpa berdiri untuk jangka masa panjang. Satu soal selidik telah dijalnkan dengan 21 responden mengenai ujian kebolehgunaan Sokongan Bawah Badan Modular Pintar dan kebolehgunaan memperoleh skor 51.31 yang berapa dalam gred “D” dengan kobolehterimaan “OK”. Semua pengimpal boleh menggunakan produk ini tanpa sebarang keraguan.

ACKNOWLEDGEMENT

I would like to thank to my supervisor, Dr Isa bin Halim from the Faculty of Industrial and Manufacturing Technology and Engineering Universiti Teknikal Malaysia Melaka (UTeM) for his unconditional guidance, support and continuous encouragement toward completing the thesis.

Furthermore, I would like to appreciate the Faculty of Industrial and Manufacturing Technology and Engineering of Universiti Teknikal Malaysia Melaka (UTeM) for providing the opportunity to conduct my project.

Besides that, I would like to thank Wentel Engineering Sdn Bhd to allow me attend for an Industrial Visit to their company, offers valuable information to carry out this project and to carry out product testing in their company.

Apart from that, a special thanks to my family and friends for their moral support in completing this degree and not forgetting, those who have directly or indirectly contributed to the realization of this thesis.

TABLE OF CONTENT

PAGES

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

IoT	Internet of Things
ICT	Information and Communication Technology
MIG	Metal Inert Gas
MSD	Musculoskeletal Disorders
SOCSO	Social Security Organization
WMSD	Work Related Musculoskeletal Disorders
AusDiab	Australian Diabetes, Obesity and Lifestyle Study
FEA	Finite Element Analysis
GMAW	Gas Metal Arc Welding
TIG	Tungsten Inert Gas
CNC	Computer Numerical Control
CAD	Computer Aided Design
ASTM	American Society for Testing and Materials
ISO	International Organization for Standardization
LED	Light Emitting Diode
HoQ	House of Quality
PMA	Pugh Matrix Analysis

LIST OF UNITS

lb/ft^3	Density
kg/m^3	Mass Density
kg/m²	Mass Index
kg	Kilogram
N/m^2	Yield Strength
ksi	Yield Strength
10^6 psi	Young Modulus
N/m^2	Tensile Strength
ksi	Tensile Strength
N/m^2	Elastic Modulus
Kg	Mass
Seconds	Time
mm	Millimeter
N	Newton
IN	Inch
m^3	Volume (Solid)
g	Gravity
m	Mass of load
mAH	Ampere-Hour

CHAPTER 1

INTRODUCTION

The first chapter of this master project report sets the stage by providing a comprehensive overview of the study. It begins with an exploration of the background of the study, delving into the intricacies of the musculoskeletal system. The focus then shifts to the health issues experienced by employees as a result of musculoskeletal problems, with specific attention given to ergonomic considerations, the working environment, and the body posture of employees while performing various tasks. The problem statement identifies and articulates the challenges faced by employees in their daily tasks, particularly the prolonged periods of standing and bending posture required in industrial settings. These challenges serve as the driving force behind the conceptualization and execution of the project, leading to the development and evaluation of innovative solutions. Within the framework of this chapter, the objectives of the project are clearly defined, encapsulating the primary goals that the research aims to achieve. Additionally, the scope of the study is outlined, providing insights into the specific focus and limitations inherent in the project. Together, these elements lay the foundation for a comprehensive understanding of the context, purpose, and boundaries of the research endeavor.

1.1 Background of Study

The industrial landscape comprises a diverse array of businesses and organizations engaged in the creation and provision of products, services, and revenue streams across various sectors such as wholesale, retail, transportation, professional services, tourism, and entertainment. Within this expansive array, the working conditions in an industrial environment are often characterized by challenges more demanding than those encountered in conventional workplaces.

Industrial workers shoulder responsibilities ranging from machinery operation and product assembly to quality assurance inspections. Their duties extend beyond operational tasks to encompass maintaining workspaces, equipment, and adherence to safety regulations. Proficiency in interpreting technical drawings, familiarity with technical software, and adept utilization of a range of tools and equipment are integral to their roles.

Given the multitude of industries, a substantial workforce is essential for their seamless operation. Consequently, an effective strategic approach is indispensable for organizing the workflow of employees within a company. This study, however, narrows its focus to metal inert gas (MIG) welders engaged in tasks requiring either standing or sitting postures. It is noteworthy that not all industries uniformly implement standing or sitting postures; specific departments mandate prolonged periods of standing or sitting.

Examining statistical data provided by Social Security Organization (SOCSO), Figure 1.1 illustrates a significant upward trend in musculoskeletal diseases. This alarming trend underscores the magnitude of the issues faced by employees, particularly those related to prolonged standing as shown in Figure 1.2 and Figure 1.3 which provides a comprehensive depiction of the exact working conditions prevalent in the manufacturing industry, contributing to the onset of musculoskeletal diseases.

Figure 1.2 and Figure 1.3 collectively highlight the challenges inherent in performing tasks in a standing position. These conditions may result in discomfort, muscle fatigue, swelling inflammation, varicose veins, and pain in the back and feet, as illustrated in Figure 1.4. The empirical evidence presented in these figures forms the basis for the critical investigation undertaken in this study to address the ergonomic issues associated with prolonged standing and sitting in industrial settings.

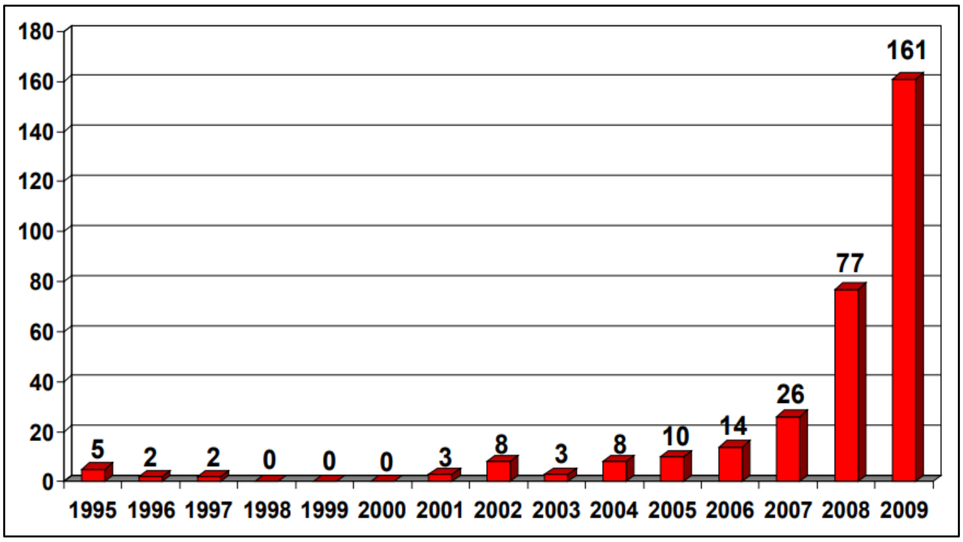

Figure 1.1: Annual musculoskeletal disease statistics reported by SOCSO 1995 – 2009. Department of Occupational Safety and Health, 2023

Figure 1.2: Prolonged standing position of worker at a fabric manufacturing company. Vietnam News (2023)

Figure 1.3: Prolong standing position of worker at an air conditioning copper pipe welding assembly line. Taizhou Youyi Automation Technology Co., Ltd. China (2023)

Figure 1.4: Prolonged standing and sitting may cause discomfort, muscle fatigue, swelling inflammation, varicose vein and pain in back and feet. Strauss Scoliosis Correction (2024)

In recent years, the impact of work-related musculoskeletal diseases (WMSD) has become increasingly evident, particularly in occupations demanding prolonged standing and maintaining an upright posture, revealing a notable association between WMSD and adverse effects on the lower back and lower extremities (Anderson et al., 2007; Coenen et al., 2016). The elevated risk observed in these occupational settings prompts a critical examination of the ergonomic challenges faced by workers, laying the foundation for the investigation undertaken in this study.

Beyond the musculoskeletal and cardiovascular impacts, the study extends its purview to the exoskeleton of the human body. While an internal endoskeleton provides structural support beneath soft tissues, prolonged standing and sitting postures can exert detrimental effects on the external exoskeleton. Unlike endoskeletons, exoskeletons offer external support to shield and enhance a person's bodily functions. Recognizing their potential to reduce fatigue, increase productivity, and assist in various physical tasks, the study acknowledges the role of exoskeletons in preventing musculoskeletal diseases. Besides that, a programmed software is developed to study the usage of the Smart Modular Lower Body Support by the MIG welder Implementation of IoT had been carried out to study on the usage of pressure sensors and postural angle sensors which seamlessly integrated with a smartphone through the Blynk cloud platform. This project is not only covered by providing comfortability to worker whereas to record and send signals to user of lower body support regarding the pressure and postural angle exerted by the welder during the MIG welding process.

This study aims to contribute significantly to addressing these multifaceted challenges by developing a “Smart Modular Lower Body Support” tailored for welders engaged in prolonged standing tasks. By doing so, it seeks to impact the workforce positively, not only by addressing musculoskeletal and occupational health but also by advancing the integration of innovative solutions to enhance work environments and employee well-being.