Faculty of Manufacturing Engineering

DEVELOP A REGRESSION MODEL FOR RELATIONSHIP BETWEEN PSYCHOPHYSICAL AND BIOMECHANICS FACTORS OF PUSH ACTIVITIES

Athirah Binti Mohd Ghazali

Master of Manufacturing Engineering (Industrial Engineering)

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ATHIRAH BINTI MOHD GHAZALI

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

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DEDICATION

Special thanks to my supervisors and treasured friends.

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ABSTRACT

In aerospace industries, many working tasks required their workers to perform the works in push-pull activity. The workers need to push or pull the mould tool in a long distance into a workplace. Performing these activity continuously throughout the working hours, may lead to an early initiation of musculoskeletal disorders (MSDs) symptoms as workers developed muscle fatigue particularly at hand muscles. Grip strength on the other hand is the force applied by the hand to push objects and is a part of hand strength. Repetitive usage of hands will create an imbalance between closing and opening (antagonist) muscles, which can lead to problem such as carpal tunnel syndrome (CTS). The primary purpose of this study is to develop regression model based on psychophysical and biomechanical factors that contributes to fatigue, in which the models can predict the relationship between the input parameters and output responses. Regression analysis is used as it is easy, user-friendly and cost-effective method to develop a model. The methodology used for this study focuses on three types of data collection which are; questionnaire and observation which conducted as the preliminary study to prove the problems that have been stated and experimental is conducted by using surface Electromyography (sEMG) and Tekscan system to evaluate the muscle fatigue and hand grip pressure force of the Lay-up workers who are performing push activity. This study investigates the hand grip pressure force for the right hand and left hand within 5 minutes and 10 minutes of time exposure while workers pushing the mould tool, and study the relationship between time exposure with hand grip pressure force and muscle fatigue. The input parameters evaluated are time exposure, hand side and body mass index (BMI); while the output responses are muscle fatigue (voltage), hand grip pressure force (left hand), and hand grip pressure force (right hand). Two polynomial equations are successfully developed and validated. The modelling validation runs are within 90% prediction interval of the developed models and their residual errors compared to the predicted values are less than 10%. The significant parameters that influenced the output responses are also identified. Muscle fatigue are influenced by time exposure, hand side, BMI, and interaction between hand side and BMI; while hand grip pressure force are influenced by time exposure, hand side, BMI, interaction between time exposure and hand side, interaction between time exposure and BMI, and interaction between hand side and BMI.

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ABSTRAK

Dalam industri aeroangkasa, banyak tugas kerja yang memerlukan mereka untuk melaksanakan kerja dalam aktiviti tolak-tarik . Para pekerja perlu menolak atau menarik alatan meletak acuan dalam jarak yang jauh ke stesen kerja. Aktiviti ini berterusan sepanjang waktu bekerja dan boleh membawa kepada permulaan awal gangguan gejala musculoskeletal (MSDs) kerana pekerja mengalami keletihan otot terutamanya pada otot tangan. Kekuatan cengkaman pula adalah daya yang dikenakan oleh tangan untuk menolak objek dan merupakan sebahagian daripada kekuatan tangan. Penggunaan tangan yang berulang-ulang dalam aktiviti ini akan mewujudkan ketidakseimbangan antara penutup dan pembukaan (antagonis) otot, yang boleh membawa kepada masalah seperti sindrom carpal tunnel (CTS). Tujuan utama kajian ini adalah untuk membangunkan model matematik berdasarkan faktor-faktor psikofizikal dan biomekanik yang menyumbang kepada keletihan, di mana model ini boleh meramalkan hubungan antara parameter (input) dan maklum balas (output). Analisis regresi digunakan kerana ia mudah, mesra pengguna dan kaedah menjimatkan kos yang sangat efektif untuk membangunkan model. Kaedah yang digunakan untuk kajian ini memberi tumpuan kepada tiga jenis pengumpulan data iaitu; soal selidik dan pemerhatian yang dijalankan sebagai kajian awal untuk membuktikan masalah-masalah yang telah dinyatakan dan eksperimen dijalankan dengan menggunakan Electromyography permukaan (sEMG) dan sistem Tekscan untuk menilai keletihan otot dan daya tekanan tangan dan genggaman daripada pekerja layup yang melakukan aktiviti penolakan. Kajian ini menyiasat daya tekanan genggaman tangan untuk tangan kanan dan tangan kiri dalam masa 5 minit dan 10 minit masa pekerja menolak alatan meletak acuan, dan mengkaji hubungan di antara pendedahan masa dengan daya tekanan genggaman tangan dan keletihan otot. Parameter 'input' dinilai ialah pendedahan masa, sisi tangan sama ada kanan atau kiri dan indeks jisim badan (BMI); manakala 'output' adalah keletihan otot (voltan), tangan daya tekanan genggaman (tangan kiri), dan daya tekanan genggaman tangan (tangan kanan). Tiga model matematik berjaya dibangunkan dan disahkan. Model yang dibina telah disahkan berada dalam 90% selang ramalan model maju dan kesilapan sisa berbanding dengan nilai-nilai yang diramalkan adalah kurang daripada 10%. Parameter penting yang mempengaruhi tindak balas output juga dikenalpasti. Otot keletihan dipengaruhi oleh pendedahan masa, sebelah tangan, BMI dan interaksi antara sebelah tangan dan BMI; manakala daya tekanan genggaman tangan dipengaruhi oleh pendedahan masa, sebelah tangan dan BMI, interaksi antara pendedahan masa dan sebelah tangan, interaksi antara pendedahan masa dan BMI, dan interaksi antara sebelah tangan dan BMI.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURES

AC	-	Alternate Current
Ag	-	Silver
AgCl	-	Silver Chloride
cm	-	Centimeters
CTDs	-	Cumulative Trauma Disorders
CTS	-	Carpal Tunnel Syndrome
CMRR	-	Common Mode Rejection Rate
dB	-	Decibel
EEG	-	Electroencephalogram
LED	-	Light-Emitting Diode
Hz	-	Hertz
mm	-	Millimeters
MMH	-	Manual Materials Handling
MPF	-	Mean Power Frequency
MSDs	-	Musculoskeletal Disorders
N	-	Newton
NPD	-	Non-Permanent Disability
PC	-	Personal Computer
PD	-	Permanent Disability
SENIAM	-	Non-Invasive Assessment of Muscles
RSIs	-	Repetitive Strain Injuries
sEMG	-	surface Electromyography
WCB	-	Workers' Compensation Board
WMSDs	-	Work Related Musculoskeletal Disorders
USB	-	Universal Serial Bus
μV	-	Micro-Voltage

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CHAPTER 1

INTRODUCTION

This chapter introduces the background information about this study and the organization of the whole study. The information of this report is organized to disclose the originality of this study. Descriptive information is given on the background of study, problem statement, research questions, objectives, scope of study, and significance of the study.

1.1 Background

In the manufacturing industry, many tasks involving manual material handling processes such as lifting heavy products, reaching materials, pushing or pulling excessive loads and bending forward of back part of body when doing tasks due to those tasks require a large degree of freedom and stable position. Pushing and pulling activities are one of the activities for manual material handling that can increase the risks of back pain problems and discomfort in the hands (Kuijer et al., 2007). The pushing and pulling activities are a continuous activity for a large segment of the workforce, including hospital workers, manufacturing workers, construction workers, or even forest workers (Jellad et al., 2013). Moreover, all of these activities are associated with the awkward posture. Awkward posture is a practical working posture when joints are not in neutral position either muscle of lumbar in strength position or compress position such as bending forward or backward of the body.

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When the processess jobs are not suitable and nearly impossible to be performed in neutral position, the workers have to bend forward their back throughout the working hours.

The theory of the awkward posture can be understood as a discomfort posture because it is a harmful position for the human body when a joint is not in its neutral range of postures and cause muscles are either less or more than resting length. Awkward posture in the workplace can cause discomfort and muscle fatigue especially in the lower extremities of workers back at the end of the working tasks. The muscles around the joint are stretched or compressed when joints are exposed to postures that involve range of movement near the extreme position. If the exposure to extreme postures is prolonged, the muscles do not immediately revert to their resting length (Hayot et al., 2012). Other than that, the workers need to raise their elbow above their shoulder, bend their neck forward greater than 30 degrees, bend their wrist downward with palm facing downward greater than 30 degrees, bend their back forward greater than 45 degrees, and squatting (Burgess-Limerick et al., 2009).

The pushing and pulling activities that take place by the workers on the other hand can contribute to discomfort and pain of hands especially in the arms and wrists area. This is due to the requirement of the activity that need the workers to grip the objects or products by using the hands, such that the workers applying pressures and forces to those objects for movement. Thus, this research is proposed to investigate the ergonomic factors and psychophysical experience that contribute to worker's fatigue and discomfort experience in the aerospace industry while performing the jobs involving push activities, analyze the biomechanical factors for worker's fatigue through and actual experiment felt and to develop and validate the regression model using ergonomic approach in studying the relationship of the worker's fatigue and hand grip pressure force.

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1.2 Problem Statement

Nowadays, productivity in the manufacturing industry always decreasing day by day. This is due to the musculoskeletal disorders (MSDs) problems that faced by the workers regarding the occupational health problems is increasing. Figure 1.1 shows the graph of occupational accidents by sector until February 2016 in Malaysia.

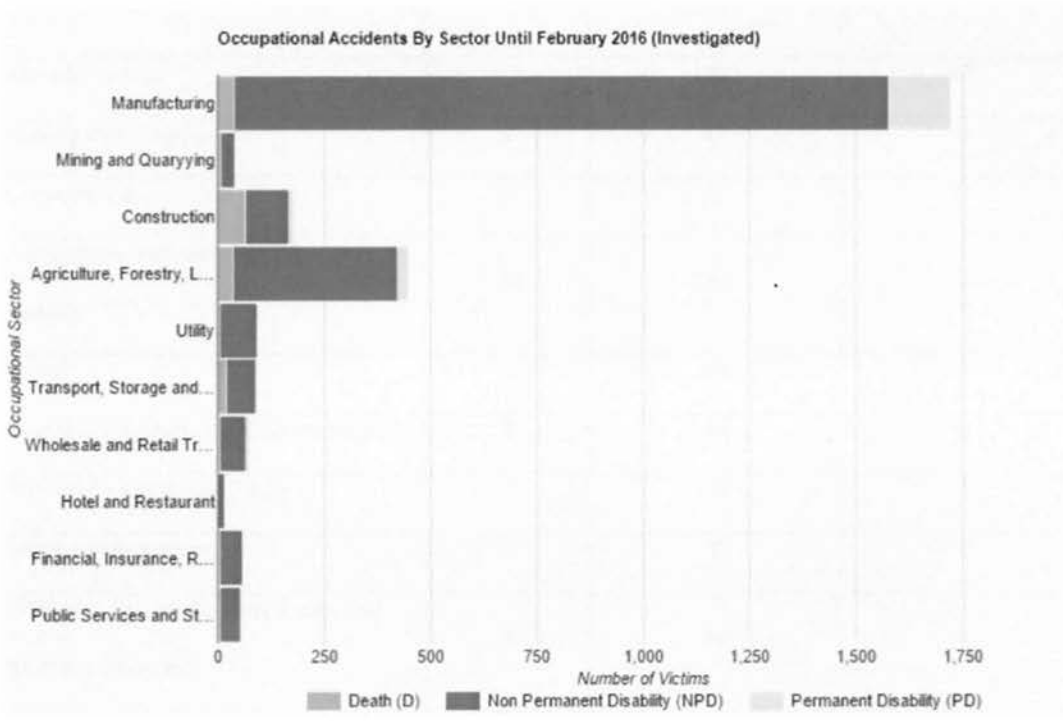

Figure 1.1: Graph of occupational accidents by sector in Malaysia (DOSH, 2016)

Based on Table 1.1, the manufacturing sector is the highest number of accidents with 40 workers were death, 1535 workers were non-permanent disability (NPD) and 147 workers were permanent disability (PD). This indicates that the manufacturing sector is no longer safe to work with.

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But, this sector has introduced Malaysia as one of the developed country to the world. Hence, the occupational problems must be reduced or eliminated in order to ensure this sector has a safe working environment.

Table 1.1: Statistical data of occupational accidents by sector (DOSH, 2016)

Occupational Sector	Death (D)	Non-Permanent Disability (NPD)	Permanent Disability (PD)
Manufacturing	47	1007	93
Mining and Quarying	0	17	0
Construction	36	55	9
Agriculture, Forestry, Logging and Fishing	26	286	9
Utility	0	65	0
Transport, Storage and Communication	7	54	0
Wholesale and Retail Trade	3	54	5
Hotel and Restaurant	0	7	0
Financial, Insurance, Real Estate and Business Services	0	48	0
Public Services and Statutory Bodies	0	50	0

In aerospace industry, almost all the jobs are performed in standing position and need an excessive force which can lead to muscle fatigue. At XYZ Sdn Bhd, a main manufacturing process is coming from lay-up process line where the operators are performing the task manually. This lines required workers to perform pushing and pulling activity in awkward posture for period of time. All workers worked on a 8 hours shift schedule.

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The shift is changed every week which is worked both; day and night shift. It was observed that the workers spent about 80% of the working hours in awkward posture to do their tasks (only neutral standing during setup ply and sitting during breaks) throughout the 8 hours working period. This is due to the activities that required the workers to push the panel every 45 minutes with awkward posture from furnace (Autoclave) to workplace (Clean Room). For instance, workers also need to push the panel in the workplace (Clean Room) before the panel is fixing to the floor. Thus, the process would be practicable in awkward posture as it requires frequent bending forward of the workers back. Furthermore, there are complaints of intense pain in those body parts from the workers of lay-up process lines which are spine, shoulder, hand arm, wrist, and fingers. When such activities requires handgrip force to move the objects, it may contribute to one of the significant effects which is known as Carpal Tunnel Syndrome (CTS) (Dun et al., 2007).

The operators are also tend to experience muscle fatigue while performing the jobs that may take to serious injuries known as Musculoskeletal Disorders (MSDs). MSDs are often caused by awkward postures, excessive force and repetition due to limited work area, standing for prolonged period of time and heavy equipments (Lei et al., 2005). Long term exposures to the muscular in compressive position may result MSDs problems. Figure 1.2 illustrates workers who are exposed to workstation operation and manual material handling (MMH) at their workstations due to pushing activity.

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