ERGONOMICS OF QUAY CRANE WORKSTATION

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Dedication

With gratitude for their patient, love and support,
i dedicated this thesis to my father, Muhammad Azmi
and mother, Wan Jaharah
and to my wife Shuhada and our child Sarah.

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ABSTRACT

Musculoskeletal Disorder (MSD) among port crane operator has been a problematic issue not only to the workers but also to the port administrative. Low back pain (LBP) has said to be the main reported cases for the MSD problem among those operators. This paper investigated the risk factors of LBP, identified the root causes, and proposed guideline to improve the situation. The occurrences of LBP were first obtained using the modified Nordic questionnaire at 143 port crane operators, which were 51 % of total population. Whole-body vibration (WBV) was then measured at seat pan to identify the exposed of vibration to the operator. Ergonomics assessment using Rapid Upper Limb Assessment (RULA) was done to justify the ergonomic of working condition. Interview with 4 operators, based on selective criteria, using a set of structured questions was also done to enhance the information received. MSD count for last 12 months showed that LBP was the prevalence factor of all the MSD claims. Univariate analysis indicated that there was significant association between duration of exposure with LBP($p < 0.001$). Binomial logistic regression showed that those operators who exposed with current working condition for more than 5 years were 7 times more prevalence to stop work due to LBP. However, there was no significant association found between characteristic and LBP. Daily exposure value A(8) measured were 0.24 m/s^2 to 0.42 m/s^2 and daily value dose vibration (VDV) exposure measured were 4.33 $m/s^{1.75}$ to 7 $m/s^{1.75}$. These value were not yet exceeded the limit value set out by EN2002/44/EC of the European Parliament. However, combination effect of long term exposure to WBV and postural stress increases the risk of LBP. In conclusion, operators of quay crane are at risk of having LBP due to the exposure of their working condition.

ABSTRAK

Gangguan Muskuloskeletal (MSD) di kalangan operator kren pelabuhan telah menjadi masalah bukan sahaja kepada pekerja tetapi juga kepada pentadbiran pelabuhan. Sakit belakang bawah (LBP) telah dikatakan menjadi punca utama yang dilaporkan dalam masalah MSD di kalangan operator kren. Kertas kerja ini mengkaji faktor-faktor risiko LBP, mengenal pasti punca, dan mencadangkan garis panduan untuk memperbaiki keadaan ini. Maklumat mengenai LBP diperolehi dengan menggunakan borang soal selidik yang diubah suai daripada borang Nordic dan sebanyak 143 operator kren, yang mana mewakili 51% daripada keseluruhan populasi, telah turut serta. Getaran seluruh badan (WBV) kemudiannya diukur pada tempat duduk untuk mengenal pasti getaran yang dirasai oleh operator. Penilaian ergonomik menggunakan Rapid Upper Limb Assessment (RULA) telah dilakukan untuk mengkaji ergonomik ketika bekerja. Wawancara bersama 4 orang operator, yang mana dipilih berdasarkan kriteria yang telah ditetapkan, menggunakan soalan berstruktur juga telah dilakukan untuk meningkatkan keberkesanan maklumat yang diterima. Bilangan MSD untuk 12 bulan lalu menunjukkan bahawa LBP merupakan faktor utama bagi laporan MSD. Analisis univariat menunjukkan bahawa terdapat hubungan yang jelas di antara tempoh pendedahan dengan LBP ($p < 0.001$). Binomial logistik regresi menunjukkan bahawa operator yang terdedah kepada keadaan kerja ini lebih daripada 5 tahun adalah 7 kali lebih tinggi untuk menghentikan kerja kerana LBP. Walau bagaimanapun, tidak ada hubungan yang jelas didapati antara ciri-ciri karekteristik dan LBP. Nilai pendedahan getaran harian A (8) yang diukur adalah antara 0.24 m/s^2 kepada 0.42 m/s^2 manakala pendedahan nilai dos getaran (VDV) harian yang diukur ialah antara 4.33 $m/s^{1.75}$ dan 7 $m/s^{1.75}$. Nilai ini tidak lagi melebihi had nilai yang ditetapkan oleh EN2002/44/EC dari Parlimen Eropah. Walau bagaimanapun, kesan gabungan pendedahan jangka panjang kepada WBV dan tekanan di postur meningkatkan risiko LBP. Secara amnya, operator kren berisiko menghadapi sakit belakang bawah akibat pendedahan terhadap kerja.

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LIST OF ABBREVIATION

ANOVA	-	Analysis of Variance
ASME	-	American Society of Mechanical Engineer
CI	-	Confidence interval
EU	-	European
DOSH	-	Department of Occupational Safety and Health
ISO	-	International Standardize Organization
LBP	-	Low Back Pain
MSD	-	Musculoskeletal Disorder
MOT	-	Ministry of Transportation
NIOSH	-	National Institute of Occupational Safety and Health
NMQ	-	Nordic Musculoskeletal Questionnaire
OHD	-	Occupational Health Doctor
PR	-	Prevalence ratio
QC	-	Quay Crane
RMS	-	Root Mean Square
RULA	-	Rapid Upper Limb Assessment
SOCSO	-	Social Security Organization
SPSS	-	Statistical Package for Social Science
SWOT	-	Strength, Weakness, Opportunity and Thread
VDV	-	Value Dose Vibration
WBV	-	Whole-body Vibration

LIST OF SYMBOLS

α	-	Reliability of Cronbach's alpha
a_w	-	Weighted acceleration
$A(8)$	-	Daily vibration exposure value
k_x	-	Weighting factor x-axis
k_y	-	Weighting factor y-axis
k_z	-	Weighting factor z-axis
p	-	Probability
T_{exp}	-	Duration of exposure
T_e	-	Reference duration
T_{mea}	-	Duration of measurement
w	-	Frequency weighting

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Ergonomics or Human Factors is a field of discipline in designing or arranging workstation or equipment so that they match or fit the workers. The purpose of ergonomics is to improve the performance of systems by improving human machine interaction and such objective can be achieved by ‘designing-in’ a better interface or by ‘designing-out’ factor in the work environment (Bridger, 2003). Thus, ergonomics is used to reduce or eliminate work related injuries such as musculoskeletal disorder (MSD) which affect many workers in various sector. In 2015, there were 708 cases related to MSD reported to Social Security Organization (SOCSO) in Malaysia, 675 cases in 2014, 517 cases in 2013 and 448 cases in 2012 respectively. This indicates an increase of 58 % of cases from 2012 to 2015. The increase trend of cases each year triggers an alarm not only to SOCSO but also to the industries.

Ergonomics issues for quay crane operator had been discussed in previous literature.(Bongers et al., 1988, Bovenzi et al., 2002, Kadir et al., 2015). Quay crane or also known as container crane are a type of gantry crane used to load and unload containers from ships. Different sizes of containers can be lifted using adjustable spreader, a type of equipment to attach to the containers. Quay crane is an essential equipment to transfer containers and widely use in every port in Malaysia. According to Ministry of Transport (MOT) Malaysia, there are seven major federal ports namely Port Klang, Johor Port, Port of Tanjung Pelepas, Kuantan Port, Penang

Port, Bintulu Port and Kemaman Port. Meanwhile, the ports in Sabah and Sarawak namely are under the jurisdiction of the State Government of Sabah and Sarawak respectively.

Under Factory and Machinery Act 1967, quay crane is included in lifting equipment that needs to be registered and inspected annually by Department of Occupational Safety and Health (DOSH) Malaysia. It is stated under section 14 that all machinery and every part thereof including all fittings and attachments shall be of sound construction and sound material free from defect and suitable for the purpose and shall be properly maintained. Unlike operator of mobile, crawler or tower crane, quay crane operator does not require a competency issued by DOSH.

1.2 Background

1.2.1 Introduction

Quay crane is a crucial machine, used extensively in port operation. Even though there a few new concepts introduced, common design of quay cranes are still widely used in port industries.

1.2.2 Quay Crane

Quay cranes can be classified into two groups, which are luffing boom type and shuttle boom types as shown in Figure 1.1 and 1.2. They are in different sizes to cater different sizes of container ships. Standardised ship sizes are mainly consists of Panamax, Post Panamax and New Panamax. These cranes have supporting frame which hold the boom and the spreader. Design of the boom can be either single girder or double girder. The boom is located above the ship so that the container can be picked up by the spreader. The crane operator will be inside the cabin, which moves along the boom as the operator transferring the container either from or to the ships using the spreader. For luffing type, the boom can be lifted upward to make way for the ships and for shuttle type, the boom can move horizontally forward or backward. This shuttle type is used especially when the port is located near an airport. The most important part of quay crane is the spreader, which is the equipment used to grab the container. Latest design of spreader can lift up to four containers simultaneously. The containers can be in standard sizes of 20ft, 30ft, 40ft or 45ft. At a certain time, the ship might not be in balance position and this requires the operator to control the spreader, whether to move up, down or slew. Typical design of spreader is equipped with four lifting wire ropes and slew mechanism. Operator needs to precisely control the motion of the spreader.

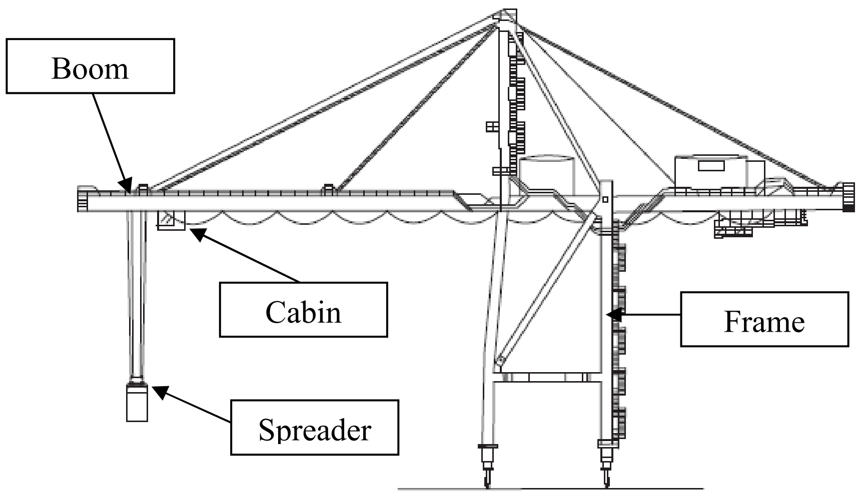

Figure 1.1 : Luffing boom type

(Source: Container Cranes (2013), ASME B30.24, American Society of Mechanical Engineer)

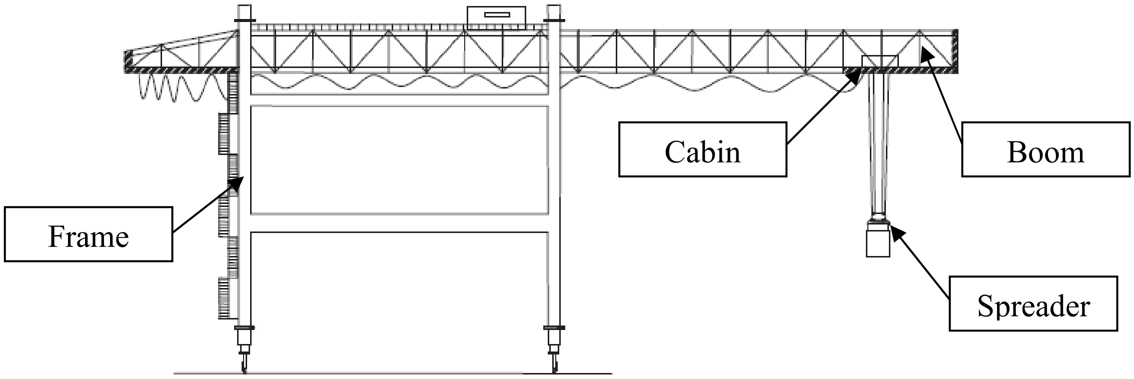

Figure 1.2 : Shuttle boom type

(Source: Container Cranes (2013), ASME B30.24, American Society of Mechanical Engineer)

1.2.3 Workstation

The spreader, which is used to lift the containers, is controlled by an operator from inside the cabin. This is where the workstation of the quay crane located. A mean of access is provided to enter the cabin and it is secured with interlock switch to ensure the door is properly shut prior to operation. Inside the cabin, there are equipments that are required in order to running the operation. The operator will be in seated position and manoeuvre either the cabin or spreader with left hand and right hand controller. Switches to activate any motion of the crane are installed within reach of the operator. To ensure safety of operation, gauges such as load indicator, wind speed, hoist height and many more are equipped at the workstation. As operator visibility is important in running the operation, glass panel is installed at a portion of the cabin including the floor of the workstation. Mean of communication is established from the operator workstation to other operator at ground cabin and on the ship.

1.2.4 Operation

The operators work in shift depends on the schedule planned by the management. Normal working flow is four hours working, then two hours rest and continue with another two hours working. They work for six days a week and rest day will depend on schedule from the management. The port is operating 24 hours a day and seven days a week, which means that the operator is needed to be ready to run the quay cranes and even if there are no ships, they need to be on standby mode. Generally speeds of load hoisting, trolley travel, gantry travel and boom hoisting will depends on different makers and models. Table 1.1 shows data found at nameplate of Mitsubishi quay crane operated in Johor Port.

Table 1.1 : Quay crane data

Technical specification	Value
Load capacity	40.6t
Lift – above top of rail	34m
Lift – below top of rail	15m
Limit of trolley travel – outreach	46.6m
Limit of trolley travel – backreach	15m
Span	30.5m
Hoisting	70m/150m/min
Trolley travel	210m/min
Gantry travel	45m/min
Boom hoisting	5.0min/raise or lower

1.3 Problem Statement

According to SOCSO, there were only 161 cases related to MSD that were reported in 2009. The reported cases increased to 238 in 2010, 268 in 2011, 449 in 2012, 517 in 2013 and 675 in 2014. However, in 2015, there were 708 cases reported to them which indicate an increase of 340% from 2009 to 2015. A brief interview with the two crane operators shows that low back pain is common problem among them and they will make use of the rest hour to relief the back pain they suffered. High number of absenteeism due to back problem was also reported by port management, thus affecting their productivity. According to Occupational, Safety and Health Act 1994 under section 15, it shall be the duty of every employer and every self-employed person to ensure, so far as is practicable, the safety, health and welfare at work of all his employees.

Recent study at port crane operators in Malaysia indicated that LBP was significantly associated with years of exposure.(Kadir et al., 2015). However, vibration measurement was not done to justify the vibration exposed to the operators. Researchers had also studied the MSD among crane operators but no direct solution provided.(Bongers et al., 1988, Bovenzi et al., 2002, Kadir et al., 2015).Thus, a solution is needed to counter the MSD problem. However, according to the port management, cost is the vital element in running their business. Based on this input, there is a need to improve the current workstation of quay crane operator with minimum cost. Furthermore, general guidelines are needed by the industries in improving ergonomics at quay crane.

1.4 Research Objectives

There are mainly three objectives of this study:

a) To identify root cause of back pain for quay crane operators;
b) To propose workstation design that improve the ergonomics features for quay crane operator at a minimum cost;
c) To provide general guidelines for safety and health of quay crane machines and operator.

1.5 Research Question

Following are the research questions:

a) What is the root cause for low back pain among quay crane operators?
b) How to improve the current workstation according to ergonomic principle at a minimum cost?
c) What can be improved in term of general guidelines for safety and health of quay crane operator?

1.6 Significant of Study

Even though quay crane has been long used in logistic operation in port, there are lacks of attention given on how to improve MSD issues among the operators. This study can demonstrate the right method on how to assess the problem and how to find the root causes. Furthermore, the findings will provide the industries with information on how to improve the low back problem and address the key elements in maintaining a safe work environment.

1.7 Organisation of Thesis

This report consists of eight chapters, as summarized in the following:

I. Chapter 1 Introduction

Chapter 1 is the introduction of the study. This chapter explains about the background of study, problem statement, research objectives, research questions and significant of study.

II. Chapter 2 Literature Review

Chapter 2 gives information on literatures that are related to this study. Main areas of research are musculoskeletal disorder (MSD), low back pain (LBP), whole-body vibration (WBV) and crane workstation.

III. Chapter 3 Research Methodology

Chapter 3 discusses on methods which applied in this study. These methods are survey, interview, direct measurement and ergonomic assessment.

IV. Chapter 4 General Findings

This chapter provides information on pilot test and demographic data which received from the questionnaire.

V. Chapter 5 Result

Chapter 5 gives information on result of analysis from questionnaire, whole-body vibration (WBV), interview and Rapid Upper Limb Assessment (RULA).

VI. Chapter 6 Design Recommendation

This chapter provides design recommendation to reduce effect of low back pain (LBP) among crane operator.

VII. Chapter 7 Discussion

This chapter discusses on the association of low back pain (LBP) with duration of exposure, stress posture, and characteristic. Aside from that, it also discusses on pain symptom, whole-body vibration (WBV), backrest, psychological factor and ergonomics.

VIII. Chapter 8 Conclusion

Chapter 8 consists of a summary of the whole study. It also provides information on study limitation, contribution, and future work.

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