UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ERGONOMIC DESIGN OF COMPUTER NUMERICAL CONTROL MILLING MACHINE USING QUALITY FUNCTION DEPLOYMENT

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

by

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ABSTRAK

Dalam operasi mengisar, mesin pengisar Kawalan Berangka Komputer atau 'Computer Numerical Control' (CNC) telah dikenalpasti sebagai salah satu penyelesaian yang berkesan untuk meningkatkan produktiviti, kecekapan dan ketepatan. Walau bagaimanapun, mesin pengisar CNC yang sedia ada menyumbang kepada masalah ergonomik seperti postur bekerja kurang selamat, keletihan otot dan keletihan mental. Tujuan kajian ini adalah untuk mereka bentuk semula mesin pengisar CNC yang sedia ada dengan mengambil kira postur pekerja. Kajian ini dilakukan melalui soal selidik untuk menentukan kehendak pekerja mengenai reka bentuk mesin pengisar CNC. Kehendak pekerja tersebut diterjemahkan menggunakan Quality Function Deployment (QFD) dan Kano untuk mendapatkan spesifikasi teknikal. Postur pekerja semasa melakukan operasi mengisar di mesin pengisar sedia ada dan mesin milling CNC yang telah direka semula telah dinilai dengan menggunakan analisis Rapid Upper Limb Assessment (RULA). Berdasarkan analisis RULA, mesin pengisar CNC yang direka semula telah menyumbang kepada postur kerja yang selamat berdasarkan skor RULA yang rendah. Kesimpulannya, kajian ini telah membuktikan bahawa penggunaan QFD dalam mereka bentuk mesin pengisar CNC yang ergonomik adalah satu penyelesaian yang berkesan untuk postur kerja yang selamat. Kajian ini mencadangkan supaya susunan ruang kerja mesin CNC perlu dikaji secara kritikal untuk meningkatkan kecekapan produktiviti.

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ABSTRACT

In milling operation, CNC milling machine has been recognized as one of effective solutions for high productivity, efficiency and precision. However, the existing CNC milling machine has contributed to ergonomics problems such as awkward working posture, muscle fatigue and mental fatigue. The aim of this study is to redesign the existing CNC milling machine by considering working posture of the machinist. This study performed questionnaire survey to determine the requirements of machinist regarding CNC milling machine design. The requirements of the machinist are then translated using Quality Function Deployment and Kano to obtain technical specification of the redesigned CNC milling machine. The working posture of machinist while performing the milling operation in existing CNC milling machine and redesigned CNC milling machine was assessed using RULA analysis. Based on RULA analysis, the redesigned CNC milling machine has improved the working posture as shown by low score of RULA. Hence, this study concluded that application of Quality Function Deployment in designing an ergonomic CNC milling machine has shown an effective solution for safe working posture. This study suggests that the workspace arrangement of CNC milling machine should be critically studied to improve productivity efficiency.

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DEDICATION

Specially dedicated to my beloved family, supervisor, lecturers and also friends for all their guidance and moral supports throughout my life.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

CAD	-	Computer Aided Design
CATIA	-	Computer Aided Three-Dimensional Interactive Application
CNC	-	Computer Numerical Control
CR	-	Customer Requirement
CS	-	Customer Satisfaction
DS	-	Customer Dissatisfaction
DOF	-	Degree of Freedom
kg	-	Kilogramme
mm	-	Millimetre
HB	-	Human Builder
HOQ	-	House Of Quality
HME	-	Human Measurement Editor
OWAS	-	Ovako Working Posture Analysis System
PDM	-	Product Data Management
QFD	-	Quality Function Deployment
REBA	-	Rapid Entire Body Assessments
RULA	-	Rapid Upper Limb Assessment
SKM	-	Sijil Kemahiran Mara
SPM	-	Sijil Pelajaran Malaysia
USA	-	United State of America
UTEM	-	Universiti Teknikal Malaysia Melaka
VOC	-	Voice Of Customer
VOE	-	Voice Of Engineer

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CHAPTER 1
INTRODUCTION

This chapter provides the information on background of study, problem statements, objectives of study, scope and limitation of study and report outlines.

1.1 Background of Study

CNC milling machine is one of machines that are usually used in the manufacturing industry and educational institutions to produce simple and complex parts from various materials. The CNC milling machine also known as machine tool that is classified into two basic forms horizontal and vertical orientations. Its invention has created a large impact on the manufacturing industry due to the fact that the machine itself can cut the parts over and over again in an absolute accuracy. The machine works by inputting the programming that already been programmed by the machinists and it will cut according to the set of the programme. The advantages of CNC milling machine can be associated with fast mass production and high precision and accuracy.

Although the CNC milling machine helps the machinist in terms of speed up the work, and precision and accuracy, the machinist may be experience ergonomic problems such as muscle fatigue due to poor working posture while operating the machine. The machinist performs the machining process in poor working posture when he or she has to twist the trunk to grasp the workpiece on the worktable located at side or rear position (Macias et al., 2009). In addition to that, the machinist might

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also experience visual discomfort due to poor position of the visual display unit attached to the machine (Ali Khan, 2012).

Nowadays, there are several methods available to improve the ergonomics-related problems in the CNC milling machine. One of the popular methods is using the Quality Function Deployment (Akao, 1993). The Quality Function Deployment or known as QFD is a concept that provides translation of customer requirements into technical requirements on each stage of the product development and production. The QFD was originally proposed by collecting and also analyzing the voice of customer (VOC) in order to develop the products with a higher quality so that it will meet the customer's needs (Chan and Wu, 2002). In this study, the House of Quality in QFD will be developed based on the machinists' requirements that are needed technically and ergonomically.

Realizing the needs to design the CNC milling machine ergonomically, this study is performed to improve the working posture of the machinist while operating the machine. To do that, the QFD was deployed in redesign the CNC milling machine.

1.2 Problem Statements

Based on literature review, the existing design of CNC milling machine has a limitation as it leads to ergonomics risks that can be summarized as follow:

1) The machinists experience muscle fatigue due to repetitive movement and awkward working posture. They tend to experience muscle fatigue, especially in the upper limb such as shoulder muscle (Brookham et al, 2010).
2) Besides, the machinist might also experience mental fatigue, which is a temporary inability to respond to a situation (Hill, 2003) that is caused by the constriction regarding usability of the machine.

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As the consequences to these ergonomic risks, the working condition will affect the productivity, efficiency and concurrently reduce the competitiveness of the industry. This is can be achieved by applying good ergonomic design so that productivity and efficiency can be improved.

1.3 Objectives of Study

The aim of this study is focusing on the ergonomic design associated with working posture when operating CNC milling machine. Consequently, the objectives of this study are:

(i) To determine customer requirements and the ergonomics features needed by the machinist with regard to the CNC milling machine design.
(ii) To redesign a CNC milling machine by considering the requirements of the machinist.
(iii) To simulate the working posture of the machinist while operating the redesigned CNC milling machine.

1.4 Scope and Limitation of Study

This study covers on the design of the CNC milling machine in terms of customer requirements and also ergonomics requirements needed by the machinist. Besides, the project will also covers on the redesign of the machine based on the specifications using simulation software. It will also covers on the ergonomic issues that are faced by the machinists, which include disorder and visual discomfort that are related with the visual display unit position and also awkward posture especially on the shoulder muscle and eye muscle (Ali Khan, 2012). At the same time, it will also covers on the Mazak CNC milling machine, which is to be used for assessment of working posture. As for the limitation of the study, simulation of working posture will be carried out on the redesigned CNC milling machine. There will be no fabrication and real assessment regarding the new machine design.

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1.5 Report Outline

In chapter one, it provides an introduction of the study, the problem statements of the study, objectives, scope and limitation of the study and also the report outlines. The main objectives of the project are to determine the technical specifications and ergonomics requirements needed by the machinists for the machine, redesign the machine as well as simulate the working posture of the machinist while operating the machine itself. The scope and limitations of the project explain the range of the project that will be done and the limits of the project itself.

In chapter two, the literature review is provided in order to support the discussion and the methodology of study. The literature review was performed by online search through journals and other reliable resources. Chapter three discusses the method applied to redesign the CNC milling machine.

Chapter four presents the data and results obtained through the questionnaire survey. Last but not least, chapter five concludes the findings of study and it provides recommendations for future improvement. Figure 1 illustrates the report outline.

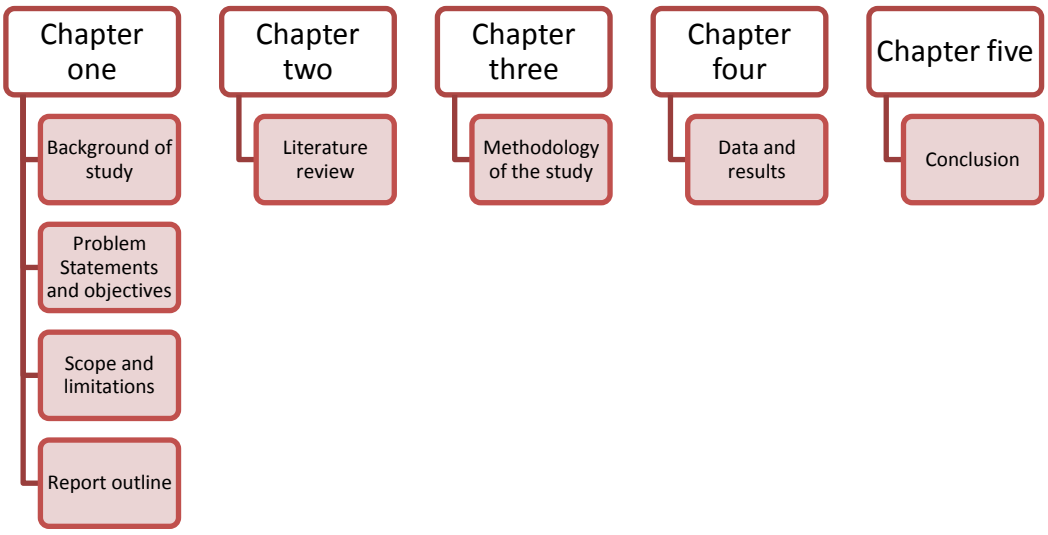

Figure 1: Illustration of the Report Outline

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CHAPTER 2
LITERATURE REVIEW

This chapter provides the literature review on technical specification and ergonomic requirements regarding CNC milling machine; and the effects of CNC milling machine design on working posture. The information and knowledge are obtained through hardbound and online journals, relevant articles and reference texts.

2.1 Determination of Customer Requirements and Ergonomics Requirements

2.1.1 CNC Milling Machine

The computer numerical control (CNC) milling machine has been developed over 200 years ago. The CNC milling machine is a machine that is used to machine solid materials into specified shapes and sizes according to technical specification. It can produce various ranges of products from simple to complex parts. Most of the CNC milling machines are run using the computer controllers. The machine is able to translate programs that may consist of specific numbers and letters in order to move the spindle to various locations and depths (Banu, 2012). The CNC milling machine can be classified into two types; vertical and horizontal orientations. The vertical milling machine has the ability to perform the movement of the spindle in vertical along the axis of Z. Due to extra degree of freedom, its performance would be better than the conventional ones. It can also improve the milling precision without even

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moving an impacting speed of the cutting tool machine; and at the same time provides a cost-efficient alternative to most of the flat surface workpiece. For the horizontal milling machine, it has a variety of cutters where the cutter can be changed easily. It generally performs a face cutting which is directly from the spindle and allows side, face and form machining in only one operation. The horizontal milling machine also contains a drive motor and gearing with a fixed position spindle. Concurrently, it allows the workpiece that is mounted to be rotated in a horizontal position, which allows the turning to be asymmetric and eccentric.

In designing a CNC milling machine, it should be designed ergonomically on which the machinists can perform milling operations in a safe working condition. In the next section, it describes on the ergonomics approach relating to CNC milling machine design.

2.1.2 Ergonomics Approach

In developing a product, designers should consider ergonomics in their product designs. The primary aim of ergonomics is to fit people, tools and environment. It considers the people's capabilities and also limitations in order to ensure tasks, equipment, information and environment works efficiently. Ergonomic is defined as a study of interactions between people and machines as well as factors that affect the interactions (Bridger, 2003). It is also referred to as a study of human characteristics for an appropriate design of both living and working environment (Kroemer et al., 2000). Another advantage of ergonomics is that making the workplace is safe to the workers so that efficiency and human well-being can be increased.

Purpose in having ergonomic criteria in a design is to eliminate any discomfort in the designs or system that can influence the performance and productivity of the system. When applying proper ergonomics intervention, there would be an improvement in terms of quality, productivity, working conditions, occupational health and safety, reduction of rejects and increases in profits (Yeow and Sen, 2002). Ergonomics approach leads to improvement of employees' wellbeing such as occupational health,

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safety, satisfactions, productivity and high work quality (Shahnavaz, 1988). Improvement in the workplace can be carried out through reactive or proactive approaches (Ali Khan, 2012). By applying ergonomics in the designs or workplaces, the levels of risk for the musculoskeletal disorders can be reduced (Macias et al., 2009).

A proactive approach in ergonomics is an approach of whereby it is to prevent any work-related musculoskeletal disorders (MSDs). The technique of this approach is by recognising risk factors in planning stage of the workplace before proceed to anticipate and reduce the risk factors. In other words, the proactive approach is applied in the design stage of workstation to avoid any potential risk for MSDs. Through proactive approach, discomfort survey is commonly used as a tool to identify any perception pain at various body locations. The advantage of this tool is that it can help to identify jobs that can contribute to potential injuries (Resnick, 1996). Furthermore, proactive approach provides a better view of the problems and actions in order to minimize the risk of MSDs at design stage of the work process or the product (Feletto et al., 2000). Example of proactive approach is design of bus driver seat where the seat is too small that has poor back support and neck posture. By using this approach, the seat has been redesigned by making the seat larger where it is more comfortable and the back support has been improved. As for reactive approach, it is an approach where it used to take action in situation that needs to be fixed. In this case, this approach is being done by deal with the current problems that are already present by using passive techniques. It is also known as an approach that used to oppose the incoming changes and tries to slow it down, stop or reverse the action (Jean et al., 2009).

In ergonomics, administrative controls and engineering controls are commonly adopted as control measures for ergonomic risks factors. Administrative method can be considered as a control on which it deals with how the work is structured. For example, rotating the workers in order to rest different muscle group of the body and reduce repetition by exchanging the workers from other workstation to different workstation. It is considered as less effective because they do not usually eliminate the risks, but instead they only lessen the duration and frequency of exposure

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towards risk condition (Michael, 2001). In terms of engineering control method, it is the most preferred method in order to control the ergonomics risk factors due to the fact that it is more permanent and effective. In other words, it is also referred to as redesign, modify or replace in terms of workplace, machines, hand tools and equipment. When the design of the workplace or machines is made, it will reduce the magnitude of the risk factors. At the same time, the likelihood of the injury will be diminished as well (Michael, 2001). For the next section, common method that is used to determine the requirements that the customers wants and needs by making surveys using questionnaires.

2.1.3 Questionnaire Survey

Questionnaire is one of the tool that is used to determine the technical specifications and the ergonomics requirements that are needed from the customers. It is widely used in order to collect important information that is needed. It allows the information to be collected from the customers and at the same time can be analysed quantitatively and systematically. Purposes of having questionnaire for survey are to obtain accurate and relevant information that will be used in designing a product based on the customer's requirements. Before starting a questionnaire, a rough idea is needed in order to get a better view of the pattern flow in terms of category of people that are suitable to be interviewed during the questionnaire survey, appropriate size of the sample and also logically related with aims and also objectives of the study (Oppenheim, 1992). In designing a proper questionnaire, the questions that will be asked need to be phrased based on certain rules, which are by using short and simple sentences in order to avoid any confusing and the sentences itself needs to be in one clause instead of two or more clauses in one sentences (Wai, 2001). Other than that, the information to be acquired one at the time and at the same time; avoid any negative questions that will be used for the survey. There are two types to administer the questionnaire; self-administrated or read out by the interviewer. Self-administrated is an approach of interview that can be sending by post, email or online, whereas for interview administered, it is an approach by using phone calls or face-to-face technique (Wai, 2001).

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