UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ANALYSIS OF WRIST AND HAND TORQUE STRENGTH FOR DESIGNING A TORQUE WRENCH

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

by

TAN CHEN MING

B051610021

960501-08-5718

FACULTY OF MANUFACTURING ENGINEERING

2020

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

Tajuk: **ANALYSIS OF WRIST AND HAND TORQUE STRENGTH FOR DESIGNING A TORQUE WRENCH**

Sesi Pengajian: **2019/2020 Semester 2**

Saya **TAN CHEN MING (960501-08-5718)**

mengaku membenarkan Laporan Projek Sarjana Muda (PSM) ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. *Sila tandakan (√)

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysiasebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)

☐ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/ badan di mana penyelidikan dijalankan)

☑ TIDAK TERHAD

Disahkan oleh:

Alamat Tetap:
74, Lebuh Bercham (T) 1/5,
Taman Seri Bercham,
31400 Ipoh, Perak.

Cop Rasmi:

Tarikh: 1/7/2020

Tarikh: 1/7/2020

*Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby, declared this report entitled "Analysis of Wrist and Hand Torque Strength for Designing a Torque Wrench" is the result of my own research except as cited in references.

Signature : ....

Author's Name : TAN CHEN MING

Date : 1 July 2020

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

Isa Halim

....

(Dr. Isa bin Halim)

....

(Ms. Nurul Wirdah binti Mafazi)

ABSTRACT

The manual operation of the milling machine requires physical strength such as lifting, repeatedly rotating the axis table, tightening and unlocking the drawbar or spindle. The fixed height of the milling machine and the absence of height-adjustable platform greatly affects the operation of the milling process as users might not be able to perform the jobs ergonomically due to mismatch of working level and their height. These work practices which are performed in awkward postures would expose the operators or users to safety issues and ergonomics risk factors. Therefore, the objectives of this study are to quantify the maximum wrist and hand torque of dominant hand at different heights in standing position, design an ergonomic torque wrench for locking and unlocking of milling machine drawbar based on the wrist and hand torque data collected as well as to fabricate and evaluate the effectiveness of the torque wrench prototype. The wrist and hand torque strength of 50 participants were measured using a torque gauge of Mark 10 Series R52 M3i Model. Interview and survey were performed to receive users' perceptions and requirement on the existing torque wrench and through Quality Function Deployment (QFD) and Pugh Concept Selection, obtain and translate the best design concept into engineering drawing in CATIA software and a prototype was fabricated. The result of the wrist and hand torque data collection shows that male generates higher wrist and hand torque compared to female. The maximum wrist torque of male is 4.54 Nm in clockwise torquing direction at shoulder height while for female is 1.92 Nm in anti-clockwise torquing direction. For the maximum hand torque measurement, the result for male and female are 10.47 Nm and 6.68 Nm respectively in clockwise torquing direction at shoulder height. The RULA analysis on the effectiveness of the design showed that there is a significant improvement in the working posture of the manikin using the redesign torque wrench as compared to the existing one with the reduction of final score from 6 to 3 for left side and 7 to 3 for right side of the manikin.

DEDICATION

Special dedication to my beloved family and friends
for giving me support, encouragement and understandings
Thank You So Much & Love You All Forever

ACKNOWLEDGEMENT

First of all, I would like to thanks the committee of Bachelor Degree Project, FYP UTeM for conducting and coordinating this project for all final year students. It provides me the opportunity to learn, understand and implement the syllabus and knowledge gained throughout the four years of study. I would also like to thanks my supervisor, Dr. Isa bin Halim who guided me patiently throughout the project and given me advice and ideas to improve my project. Next, I want to express my gratitude to my co-supervisor, Ms. Nurul Wirdah binti Mafazi for guiding me on the statistical data analysis, because of her willingness and generosity in sharing her knowledge, I am able to do the project in a proper way. Without both of the supervisors, my Final Year Project would not go this well and smoothly. Besides, I would also like to convey my thanks to all of the staffs and assistant engineers and students that I had asked for assistance, because they always being patient in giving me advices and guidance that helps me a lot throughout my data collection and fabrication of prototype. Last but not least, a special appreciation to my family as they always show their greatest support in every way and my friends who always give me supports and assistance whenever I need them.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACW	-	Anti-clockwise
ANOVA	-	Analysis of variance
BMI	-	Body Mass Index
CAD	-	Computer-aided design
CW	-	Clockwise
EMG	-	Electromyography
FKP	-	Faculty of Manufacturing Engineering
HDM	-	Human Digital Models
HOQ	-	House of Quality
MPS	-	Malaysian Pharmaceutical Society
MSD	-	Musculoskeletal disorder
MVC	-	Maximum voluntary contraction
NIST	-	National Institute of Standards and Technology
QFD	-	Quality Function Deployment
RSIs	-	Repetitive strain injuries
RT	-	Real time
RULA	-	Rapid Upper Limb Assessment
SD	-	Standard deviation
SOP	-	Standard Operating Procedures
UTeM	-	Universiti Teknikal Malaysia Melaka
WMSD	-	Work-related musculoskeletal disorder

LIST OF SYMBOLS

mm	-	millimetre
cm	-	centimetre
m	-	metre
%	-	percent
Ncm	-	Newton centimetre
Nm	-	Newton metre
kg	-	kilograms
F	-	Force
m	-	mass
a	-	acceleration
τ	-	Torque
r	-	distance
θ	-	angle
!	-	factorial

CHAPTER 1
INTRODUCTION

This chapter introduces the background of study which related to the design of torque wrench used for the milling machine in the Faculty of Manufacturing Engineering (FKP) machine shop of Universiti Teknikal Malaysia Melaka (UTeM). Besides, it includes problem statements related to ergonomics issues encountered during the attachment and detachment of drawbar of the conventional milling machine using the existing torque wrench. The objectives, scope and significance of study will be shown followed by a brief summary that summarises the whole chapter.

1.1 Background of Study

Milling is a machining operation metal removal process using rotating cutting tool. The cutting process is by feeding the work piece past a rotating multi-toothed milling cutter. The milling cutter has multiple cutting edges that rotates at high speed and removes the metal layer by layer and its axis of rotation of is against the direction of the feed. This orientation between the tool axis and the feed direction is one of the characteristics that can differentiate milling from drilling. In drilling, the cutting tool and the feed direction are in parallel orientation. The surface of the work piece that undergoes milling process may be flat, angular or curved as well as be milled to any combination of shapes. The machine for holding the work piece, rotating the cutter, and feeding is known as the milling machine.

The milling machine in UTeM FKP machine shop is a vertical milling machine. At the top of the milling machine, there is a drawbar. A drawbar is the main part of the milling machine which provides a clamping mechanism to hold the tool holder or chuck. The cutting tool or spindle will be installed into the chuck. When the machine is on, the chuck will rotates which further rotates the cutter. The cutter will be fixed and only in rotational motion. The cutting process is through the controlling of the axis of work piece to be cut into desired shape. The general procedures of working a milling machine are as follow:

1. Fix the work piece onto the vise.
2. Clamp the right type of chuck into the machine.
3. Install the appropriate type of cutter into the chuck.
4. Switch on the power and adjust the desired speed for machining. Then, run the machining process.

Since it is conventional, the operation of the milling machine requires manually operated procedures such as lifting, repeatedly rotating the axis table, tightening and unlocking the drawbar or spindle. These work practices which are physically demanding would expose the operators or users to ergonomics risk factors. The ergonomics risk factors usually occur in combination. For example, force exertion with repetition, repetitive force exertion in awkward postures and so on. Exposure to these risk factors put users at high level of Work-related Musculoskeletal Disorders (WMSD) risk.

The WMSD is a painful disorder that affects the human body structures of muscles, tendons, ligaments, nerves etc. It is sometimes called repetitive motion injuries or repetitive strain injuries (RSIs). By referring to the specific part of body structures affected, the disorders will be referred as Carpal Tunnel Syndrome, Tension Neck Syndrome, tendonitis, muscles or tendons strain and so on. Therefore, ergonomics is important and should be a concern in the workplace so that WMSD can be prevented instead of treated.

Ergonomics is the study of law of work that involves designing and optimizing products, workplaces or systems for people to reduce discomfort and risk of injuries as well as improve the performance and satisfaction. In the era of globalization, technologies change, the design of tools and workplaces has to be improved as well to meet the requirement and abilities of the human body. The improvement of human-product, human-environment and human-system interactions can be achieved through the study of human capabilities and limitations.

1.2 Problem Statement

Problem statement is the description of issues or negative points of current state of a product or process. It shows the difference between the desire view and current situation. Based on the current situation during the operation of the conventional milling machine in the FKP machine shop, there are a few issues observed.

There are two models of conventional milling machine in the FKP machine shop, which are the Enrique Holke vertical milling machine and the Bridgeport vertical milling machine. Both milling machines work with similar operations but in terms of the machine size, the Enrique Holke vertical milling machine is higher than the Bridgeport vertical milling machine. Figure 1.1 and Figure 1.2 show the Enrique Holke and Bridgeport vertical milling machines respectively.

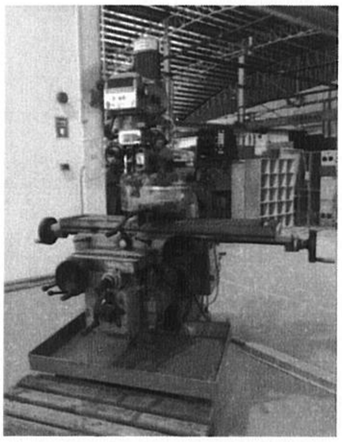

Figure 1.1: Enrique Holke milling machine

Figure 1.2: Bridgeport milling machine

To install the cutting tools into the chuck, users have to manually tighten or unlock the drawbar at the top of the machine. The reaching of the drawbar is difficult since the machine height is not adjustable and there is no any height-adjustable platform as well. This issue greatly affects the operation of the milling process as users might not be able to perform the jobs ergonomically due to mismatch of working level and their height.

1.2.1 Awkward Posture when Tightening and Unlocking the Drawbar

Torque or moment is a vector quantity of force that allows an object to rotate about an axis. Its direction follows the direction of rotation. In rotational kinematics, torque takes place of the force in the Newton's Second Law of Motion equation ($F = ma$). The equation of torque is derived as

$$\tau = F \text{ x } r \sin \theta$$

where r is the distance measured from the axis of rotation where the linear force is applied, F is the linear force and θ represents the angle between F and r. In order to achieve maximum torque, the force applied should be perpendicular to the axis of rotation. Figure 1.3 shows the equation of torque for a wrench and nut.

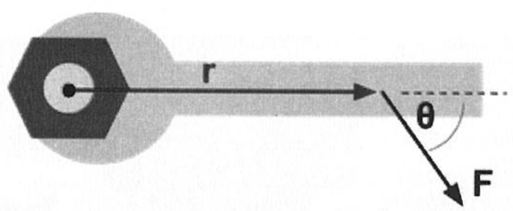

Figure 1.3: Torque equation shown for a wrench and nut. Retrieved from https://www.khanacademy.org/science/ap-physics-1/ap-torque-angular-momentum

However, the drawbar is designed at the top of the milling machine and users are hard to reach for the drawbar. During the operation, the torque wrench will be at inclined orientation. Therefore the force applied will not be at 90 degrees to the center of rotation and the torque produced will not be at maximum. Hence, extra force has to be applied during the operation of tightening and unlocking of the drawbar. Figure 1.4 shows the drawbar of the milling machine and the operation is shown in Figure 1.5.

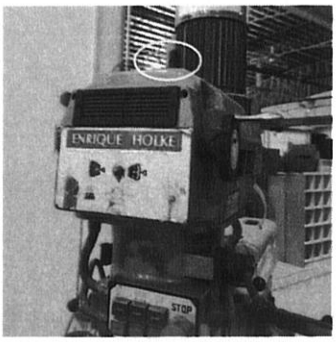

Figure 1.4: The milling machine drawbar

Figure 1.5: A user trying to reach the drawbar

Wood *et al.* (1999) and Attwood (2002) determined that the highest torque exertion is at shoulder height, but according to the current state of tightening and unlocking of drawbar as shown in Figure 1.6, users cannot produce maximum torque at overhead height.

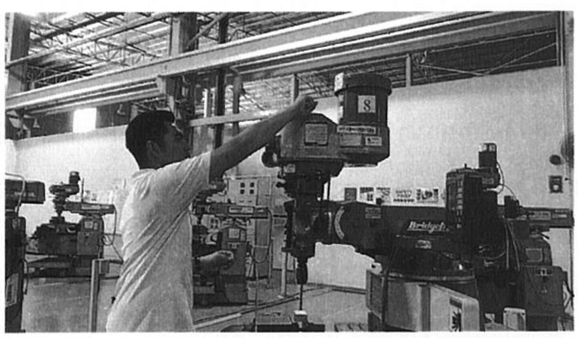

Figure 1.6: The drawbar is at overhead height

Furthermore, the short handle of the torque wrench does not provide essential space between the users and the machine bed when reaching for the drawbar causing the users to work in an awkward posture. Based on the fundamentals ergonomics principle, workers should always maintain neutral postures. Neutral postures reduce the stress applied to muscles, tendons, nerves and bones and enable maximum control and force exertion. The opposite of a neutral posture is an "awkward posture." Awkward postures diverts from the neutral posture towards the extremes in range of motion. This increases the stress on the worker's musculoskeletal system.

As mentioned in the background of study, the combination of ergonomics risk factors such as repetitive work exertion in awkward postures may expose users to higher risk of WMSD. Even though a standing platform is added, the height is still hard to reach. At a long term view, users especially technicians who often operate the machine in awkward posture are at a higher risk of getting WMSD.

Besides, users' eye sights are not able to reach the level of the drawbar. This situation might lead to safety issues during the operation. For smaller size users especially females, they may tip-toe their feet to reach the drawbar leading their bodies to be in an unbalance posture. Slip and fall may occur due to this dangerous form of body posture. Therefore, the attachment and detachment of the drawbar are usually performed by the technicians due to safety reason.

1.2.2 Contact Stress on the Grip of Torque Wrench

Contact stress happens when the soft tissue of the body continuously contact and rub against a hard object or surface. Tissue damage occurs as a result due to repeatedly exposure to mechanical stress or pressure over a period of time. All the tools and equipments used in the machine shop including the existing torque wrench are made of hard metals. During the operation when the palm is applying force to the handle of the torque wrench, contact stress occurs. The fundamental ergonomics principle states that contact stress should be minimized to avoid the exposure to the ergonomics risk factors that in long term would bring harm to human body. Figure 1.7 and Figure 1.8 demonstrate contact stress that refers to on-going contact between a part of the body and a hard surface.

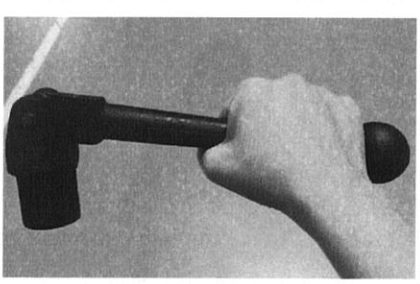

Figure 1.7: Tool with hard edge

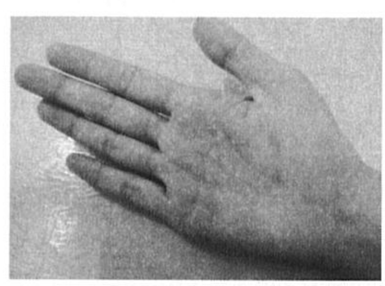

Figure 1.8: Redness is observed on the palm

1.3 Objectives

The objectives are as follows:

(a) To quantify the maximum wrist torque and hand torque of dominant hand at different heights in standing position.

(b) To design an ergonomic torque wrench for locking and unlocking of milling machine drawbar based on the wrist and hand torque data collected.

(c) To fabricate and evaluate the effectiveness of the torque wrench prototype in locking and unlocking of milling machine drawbar.

1.4 Scopes of Study

The project is to design a torque wrench that allows the vertical milling machine users to work in an ergonomics friendly condition. This study is mainly focus on the torque wrench used for the conventional vertical milling machines in the FKP machine shop.

For the data collection of the maximum wrist torque and hand torque, the participants involved are only Malaysian young adults who are studying under the undergraduate programs of Faculty of Manufacturing Engineering (FKP) and are free from disabilities and injuries on arm and wrist. The wrist torque data collected are limited to the dominance hands of participants in neutral position for waist height, elbow height and shoulder height while the hand torque study is focusing on the participants' dominance hands in pronation for shoulder height, eye height and overhead height.

The design of the torque wrench is mainly needed to solve the issues mentioned in the problem statement. The concepts of design should be based on the feedbacks of Universiti Teknikal Malaysia Melaka (UTeM) FKP users including the lecturers, assistant engineers and students. The fabrication of prototype basically has to meet the criteria of low cost, adjustable and making minor adjustment on the existing torque wrench using available materials.

1.5 Significance of Study

There are some benefits that can be gained after the completion of this study. First of all, the data of hand and wrist torque strength collected are of the Malaysian young adults. These data will be used for the improvement of torque wrench design in this project. While in future, these data can be a reference for further analyses of other studies or projects. Next, by designing and building a new torque wrench that meets the requirement of the users, working conditions and environment, improvement can be achieved in the aspects of safety, hand tool functionality and ergonomics factor. It will bring ease and comfort to the vertical milling machine users during milling operation, reduce the risk of getting injuries as well as allow users to work in an ergonomics friendly condition.

1.6 Framework Structure of Study

To summarize the content of the project, the framework structure of study is shown in Figure 1.9.

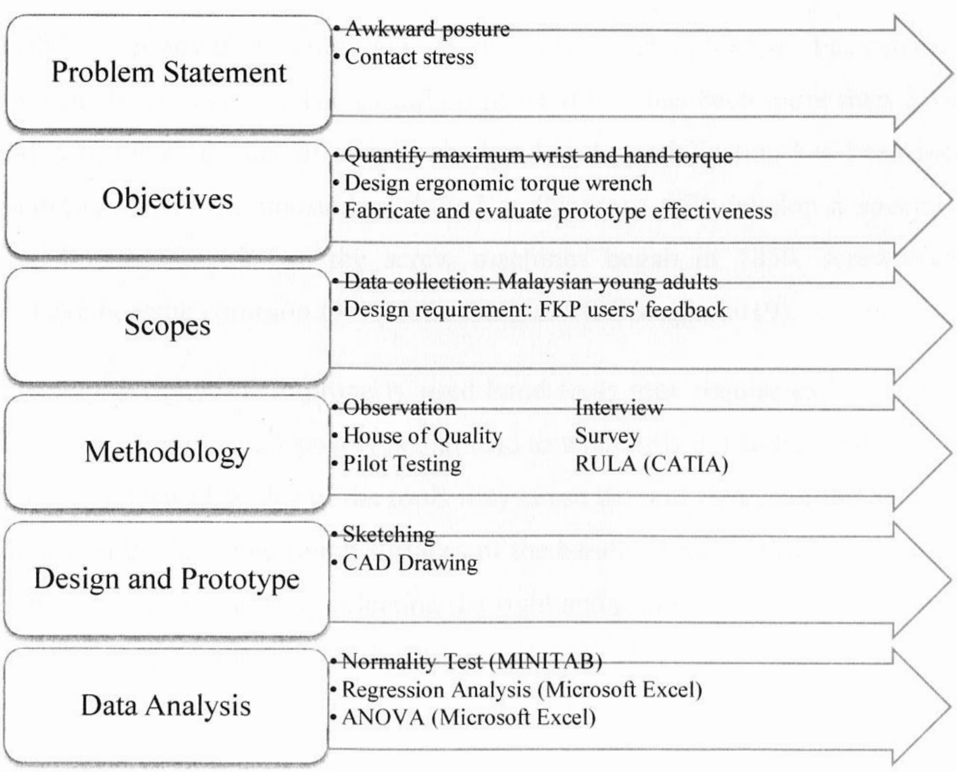

Figure 1.9: Framework of Study