DESIGN OF A GRIP HANDLE FOR MANUAL LIFTING AND CARRYING OF LONG METAL BAR

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

by

TUNG FANG WEN

B051410167

941127-10-5032

FACULTY OF MANUFACTURING ENGINEERING

2018

DECLARATION

I hereby, declared this report entitled “Design of a Grip Handle for Manual Lifting and Carrying of Long Metal Bar” is the result of my own research except as cited in references.

Signature : ……

Author’s Name : TUNG FANG WEN

Date : 6 JUNE 2018

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 Bachelor of Manufacturing Engineering. The member of the supervisory committee is as follow:

…….....

(DR.ISA BIN HALIM)

ABSTRAK

Sektor pembuatan merangkumi pelbagai kategori industri termasuk logam, kulit, kertas, kayu dan lain- lain industri. Tugas pengendalian manual dianggap sebagai aktiviti yang kerap dilakukan dalam industri pembuatan. Selain itu, ia juga dikenalpasti sebagai punca utama kecederaan pekerjaan seperti sakit belakang dan kecederaan otot berangka. Dalam kajian ini, kajian tertumpu pada mengangkat manual dan membawa bar logam panjang. Tujuan kajian ini adalah untuk merekabentuk satu pemegang bar logam untuk memberikan prestasi yang lebih baik dari segi penguasaan cengkaman, keselesaan subjektif dan produktiviti kerja. Kajian ini menggunakan pengukuran kekuatan cengkaman tangan untuk menentukan asas kekuatan cengkaman tangan yang optimum di kalangan pemuda lelaki Malaysia. Di samping itu, faktor-faktor keselesaan dan ketidakselesaan diperolehi dengan menyebarkan soal selidik keselesaan kepada pengguna dan produktiviti kerja mereka ditentukan dengan menjalankan eksperimen kajian masa. Selain itu, kajian ini juga menggunakan teknik kumpulan fokus dan House Of Quality (HOQ) untuk mendapatkan keperluan pengguna dan spesifikasi teknikal reka bentuk pemegang bar logam yang dikehendaki. Kemudian, enam konsep telah dilakar dan konsep telah ditapis dan menfokuskan pilihan dengan menggunakan kaedah pemilihan konsep. Seterusnya, prototaip telah difabrikasi dan keberkesanan prototaip telah dinilai dengan menggunakan soal selidik keselesaan, pengukuran aktiviti otot dan kajian masa. Selain itu, kajian ini menghitung pulangan pelaburan untuk memberikan anggaran tempoh bayaran balik bagi memastikan keuntungan syarikat. Kajian ini menyimpulkan bahawa prototaip pemegang bar logam yang telah dibangunkan tidak menjejaskan kekuatan genggaman , meningkatkan keselesaan subjektif, mengurangkan usaha otot dan membantu produktiviti kerja semasa pengendalian manual bar logam panjang.

ABSTRACT

Manufacturing sectors are broadly embraces a wide range of categories of industry which are including metal, leather, paper, wood and other industry. Manual handling task is considered as one of necessary activities in the manufacturing industry. Besides, it is also recognized as a major cause of occupational injuries as like back pain and musculoskeletal injuries. In this study, the investigation is focused on the manual lifting and carrying of a long metal bar. In order to reduce the risk of injuries, the aim of this study is to design a grip handle to provide a better performance in term of grip exertion, subjective comfort and work productivity. This study applied hand grip strength measurement to determine the baseline of the optimum hand grip strength among the Malaysian male youth. In addition, the factors of comfort and discomfort were obtained by distributing the comfort questionnaire to the participant and their work productivity was determined by conducting a time study experiment. Besides, the study also applied the focus group technique and House Of Quality (HOQ) to figure out the prior user requirement and technical specification of the desired design of grip handle. Then, six concepts were sketched and the concepts have been screened and narrowed down the choices by using concept selection method. Next, the prototype was fabricated and the effectiveness of the prototype was evaluated by using the similar comfort questionnaire and time study experiment. Besides, this study has been conducted the return on investment to provide the estimation of the payback period in order to ensure the profitability of company. This study concluded that the developed grip handle prototype has improved in term of grip exertion, muscle effort, subjective comfort and work productivity during manual handling of long metal bars.

DEDICATION

For my beloved family, project supervisor, workshop technician and friends that always believe in me and giving me moral support, money, cooperation, encouragement and also understandings to complete this project and report. Thank you so much.

ACKNOWLEDGEMENT

I would like to pay special thankfulness and appreciation to my respected supervisor, Dr Isa bin Halim. His kindness, sage advice, insightful criticisms and mentorship guided me through the process. His vital support and encouragement assisted me to achieve my goal and turned my project a success.

Besides, I would like to show my gratitude to my best friends who provided me with unfailing support and continuous encouragement in completing this project. They had given their critical suggestion and helped me develop my ideas throughout my project. Thanks for the great friendship.

Then, I would like to take this opportunity to thank to the technician at the workshop that helped me a lot to complete this project within the limited timeframe. They answered my doubts and questions with full kindness and patient.

Finally, I would like to thank everybody who was important to this FYP report, as well as expressing my apology that I could not mention personally each one of you.

TABLE OF CONTENT

Abstrak		i
Abstract		ii
Dedication		iii
Acknowledgement		iv
Table of Content		v
List of Tables		xii
List of Figures		xiv
List of Abbreviations		xvii
List of Symbols		xviii

CHAPTER 1: INTRODUCTION

1.1	Background of Study	1
1.2	Problem Statement	4
1.3	Objectives	7
1.4	Scope and Limitation of Study	8
1.5	Significance of Study	8

CHAPTER 2: LITERATURE REVIEW

2.1	Overview of Hand Grip Strength	10
2.1.2	Hand grip strength measurement tool	11
2.1.3	Hand grip strength measurement procedures	12

2.1.3.1 Participant screening form 12

2.1.3.2 American Society of Hand Therapist (ASHT) protocol 13

2.1.3.3. Calibration of Jamar hand dynamometer 13

2.1.3.4 Wrist and forearm position 14

2.1.3.5 Hand dominance 14

2.1.3.6 Interval between measurements 15

2.1.4 Factors affect hand grip strength 15

2.1.4.1 Age 15

2.1.4.2 Gender 16

2.1.4.3 Handedness 17

2.1.4.4 Height and weight 17

2.1.4.5 Body positon 17

2.1.4.6 Handle size or diameter 18

2.1.4.7 Handle length 19

2.1.4.8 Handle shape 19

2.1.4.9 Handle material 20

2.1.4.10 Handle curvature 20

2.1.4.11 Handle texture 21

2.1.4.12 Tool weight 21

2.1.4.13 Grip span 22

2.1.4.14 Handle interface 22

2.2 Overview of Electromyography (EMG) 23

2.2.1 EMG electrode 23

2.2.2 Considerations of EMG measurement 24

2.3 Overview of Subjective Measurement 24

2.3.1 Subjective comfort 25

2.3.1.1 Comfort questionnaire 25

2.3.2 Subjective discomfort 26

2.3.2.1 Rating perceived exertion (RPE) 27

2.3.3 Importance of subjective comfort and discomfort 29

2.4 Product Design 29

2.4.1 Focus group 30

2.4.1.1 Importance of focus group 30

2.4.1.2 Limitation of focus group 31

2.4.2 Concept selection 31

2.5 Difference between previous studies and current study 33

CHAPTER 3: METHODOLOGY

3.1 Measure and Analyse the Maximum Hand Grip Strength of Dominant Hand 36

3.1.1 Calibrate the Jamar hand dynamometer 37

3.1.2 Apply consent and create participant screening form 38

3.1.3 Apply American Society of Hand Therapist (ASHT) protocol 39

3.1.4 Perform pilot study 40

3.1.5 Execute actual data collection 40

3.1.6 Transform raw data into database 40

3.2 Analyse Hand Grip Strength, Muscle Contraction, Subjective Comfort and Work Productivity 41

3.2.1 Data analysis 41

3.2.2 EMG measurement 44

3.2.3 Subjective comfort questionnaire 45

3.2.4 Time study 45

3.3 Design and Fabricate a High Fidelity Prototype of Handle for Metal Bar Handling 46

3.3.1 Focus group technique 46

3.3.2 House of Quality (HOQ) 47

3.3.3 Conceptualization Design 48

3.3.4 Concept selection 49

3.3.5 Prototype development 51

3.3.6 Effectiveness of the developed prototype 51

3.3.7 Experimented tasks 51

3.3.8 Estimation of return on investment (ROI) 52

3.4 Summary 53

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Measurement of Maximal Hand Grip Strength of Dominant Hand 57

4.1.1 Participants and basic data 58

4.1.2 Demographic information 58

4.1.3 Findings of measurement of maximum hand grip strength 61

4.1.4 Descriptive statistics of hand grip strength at different forearm position 62

4.2 Analysis of Lifting and Carrying Metal Bar (Existing Method) 65

4.2.1 Participant data 65

4.2.2 Experimental tasks 66

4.2.3 Hand grip strength 66

4.2.4 Electromyography analysis (EMG) 67

4.2.5 Subjective comfort level 70

4.2.6 Productivity 71

4.2.7 Summary of analysis using existing method 71

4.3 Design and Fabricate a High Fidelity Prototype of grip Handle 72

4.3.1 Customer requirements 72

4.3.2 House of Quality (HOQ) for grip handle 73

4.3.2.1 Summary of HOQ for grip handle 74

4.3.3 Conceptual design for grip handle 74

4.3.3.1 Existing grip handle to lift and carry metal bar 77

4.3.4 Concept selection for grip handle 77

4.3.4.1 Concept screening for grip handle 78

4.3.4.2 Summary of concept screening for grip handle 79

4.3.4.3 Concept scoring for grip handle 79

4.3.4.4 Summary of concept scoring for grip handle 80

4.3.5 Final design of grip handle 81

4.3.6 House of quality of lifting wedge 82

4.3.6.1 Summary of HOQ of lifting wedge 83

4.3.7 Conceptual design for lifting wedge 83

4.3.7.1 Existing lifting wedge in the market 85

4.3.8 Concept selection of lifting wedge 86

4.3.8.1 Concept screening of lifting wedge 86

4.3.8.2 Summary of concept screening of lifting wedge 86

4.3.8.3 Concept scoring of lifting wedge 87

4.3.8.4 Summary of concept scoring of lifting wedge 87

4.3.9 Final design of lifting wedge 88

4.3.10 Prototype evaluation tasks 88

4.3.10.1 Measurement of maximum hand grip strength 89

4.3.10.2 Comparison of hand grip strength between existing method and proposed prototype 90

4.3.10.3 Electromyography (EMG) analysis 91

4.3.10.4 Comparison of EMG analysis between existing method and proposed prototype 93

4.3.10.5 Subjective comfort level 95

4.3.10.6 Comparison of subjective comfort level between existing method and proposed prototype 96

4.3.10.7 Productivity 96

4.3.10.8 Comparison of productivity between existing method and proposed prototype 97

4.3.10.9 Summary of prototype evaluation tasks 97

4.3.11 Estimation of return on investment (ROI) 98

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Maximum Hand Grip Strength of Dominant Hand among Malaysian Youth with Forearm at Vertical, Supination and Pronation Positon 99

5.2 Hand Grip Strength, Muscle Contraction, Subjective Comfort Level and Work Productivity while Using Existing Method 100

5.3 Design and Evaluation of the Developed Prototypes 100

5.4 Recommendations for Future Study 101

5.5 Sustainable Design Development 101

5.6 Engineering Complexity and Life Long Learning 101

REFERENCES 102

APPENDICES

A Participant Screening Form 117

B Comfort Questionnaire 119

C Raw Data of Hand Grip Strength Measurement 121

D Demographic Information of Participants Involved in Experiments 125

E SOP and Consent Form of Experiments 126

LIST OF TABLES

2.1	Borg CR-10 scale	28
2.2	Borg RPE scale	28
2.3	Difference between previous studies and current study	33
3.1	Representative symbol for interrelationship matrix	48
3.2	Representative symbol for co-relationship matrix	48
3.3	Concept screening matrix	50
3.4	Concept scoring matrix	50
3.5	Record from for cost savings	53
4.1	Mean and standard deviation values of the variables	60
4.2	Descriptive statistics of hand grip strength at different forearm position	63
4.3	Average readings of each demographic data	65
4.4	Representative symbol for interrelationship matrix	73
4.5	Rating scales for concept screening matrix	78
4.6	Concept screening matrix for grip handle	78
4.7	Rating scales of concept scoring matrix	79
4.8	Concept scoring matrix for grip handle	80
4.9	Concept screening matrix for lifting wedge	86

4.10	Concept scoring matrix for lifting wedge	87
4.11	Comparison of EMG result of brachioradialis muscle	93
4.12	Comparison of EMG result of biceps brachii muscle	94
4.13	Comparison of time spent to complete the experiments	97
4.14	Occupational health saving costs	98
4.15	Payback period	98

LIST OF FIGURES

1.1	Manual carrying of long metal bar	2
1.2	Improper method to carry heavy load	5
1.3	Workers carry a large size of load	5
1.4	Worker unable to hold firmly on the load	6
1.5	Wobbling metal bar	7
2.1	Jamar hand dynamometer	12
2.2	Illustration of the measurement of hand grip strength	13
2.3	Example of comfort questionnaire	26
2.4	Concept screening matrix	32
2.5	Concept scoring matrix	33
3.1	Illustrations of calibration of Jamar hand dynamometer	38
3.2	Observation of resultant reading on Jamar hand dynamometer	38
3.3	Measurement at vertical wrist posture	40
3.4	Example of the database table	41
3.5	Output of descriptive statistics	43
3.6	Detail information obtained from regression analysis	43
3.7	Normal probability plot by using regression analysis	44

3.8	Position of electrode on the observed muscle	45
3.9	Flow chart of methodology to achieve first objective	54
3.10	Flow chart of methodology to achieve second objective	54
3.11	Flow chart of methodology to achieve third objective	56
4.1	Percentage of each age group	58
4.2	Percentage of ethnics	59
4.3	Percentage of hand dominance	60
4.4	Average of maximum hand grip strength of different forearm position	61
4.5	Normal distribution of hand grip strength at neutral position	64
4.6	Normal distribution of hand grip strength at supination position	64
4.7	Normal distribution of hand grip strength at pronation position	64
4.8	Average readings of hand grip strength after execution of both experiments	67
4.9	Descriptive statistics and box plot for the EMG of brachioradialis muscle	68
4.10	Descriptive statistics and box plot for the EMG of biceps brachii muscle	69
4.11	Average comfort level for each descriptors	70
4.12	HOQ for grip handle	73
4.13	Concept A of the grip handle	74
4.14	Concept B of the grip handle	75
4.15	Concept C of the grip handle	75
4.16	Concept D of the grip handle	76
4.17	A nylon sling	77
4.18	Final design of grip handle	81

4.19	HOQ of lifting wedge	82
4.20	Concept A of lifting wedge	83
4.21	Concept B of lifting wedge	84
4.22	Concept C of lifting wedge	84
4.23	Market existing product of lifting wedge	85
4.24	Final design of lifting wedge	88
4.25	Measurement of maximum hand grip strength	89
4.26	Comparison of hand grip strength for experiment of lifting	90
4.27	Comparison of hand grip strength for experiment of carrying	90
4.28	Descriptive statistics and box plot for the EMG of brachioradialis muscle	91
4.29	Descriptive statistics and box plot for the EMG of biceps brachii muscle	92
4.30	Average comfort level for each descriptors	95
4.31	Comparison of the average comfort level for each descriptors	96

LIST OF ABBREVIATIONS

ANOVA	-	Analysis Of Variance
ASHT	-	American Society of Hand Therapists
BMI	-	Body Mass Index
EMG	-	Electromyography
HOQ	-	House Of Quality
LPD	-	Local Perceived Discomfort
MANOVA	-	Multivariate Analysis Of Variance
NIOSH	-	National Institute of Occupational Safety and Health
ROI	-	Return On Investment
RPE	-	Rating Perceived Exertion
SOCSO	-	Social Security Organization
VAS	-	Visual Analogue Scale

LIST OF SYMBOLS

%	-	Percentage
kg	-	Kilogram
mm	-	Millimetre
cm		Centimetre
RM	-	Ringgit Malaysia
µV		Microvolt

CHAPTER 1

INTRODUCTION

This chapter provides a brief introduction to the developed project. The introduction starts with a background of study which briefly describes current information or relevant previous researches with regard to the topic discussed. A description of the existing problem related to the issues is presented in the problem statement afterward. It is followed by the objective to point out the goals that desire to be achieved. Then, it comes to the scope which defines the project boundary or limitations. By the end of this chapter, the project significance is presented to state the importance of this study.

1.1 Background of study

Manual handling is a physical activity that involves various activities that require the consumption of force exerted by a person to perform the tasks like lifting, lowering, pushing, pulling, carrying, moving or holding an object. Manual handling takes place in almost all working environments, for example, manufacturing, construction, agriculture, hotels and restaurants. Among the examples, manual handling activities are most frequent occurred at manufacturing industry and construction sites such as transporting heavy materials like metal bar, steel plate and others.

Manual handling of the metal bar has been recognized as a necessary activities in manufacturing industry and construction sites. The common manual handling activities

involved with metal bar are including the task of lifting and carrying the metal bars. The ways to perform such activities depend on some variables such as the weight of the metal bar and distance between the starting point of carrying the metal bar and destination for unloading the metal bars. The workers are usually perform the activities with bare hand if the metal bar is lightweight whereas they may complete the task of carrying heavy metal bar by using trucks or trolley. Besides, they usually depend upon on the assist of mechanical aids like a forklift to lift or carry the metal bar for a long distance between work stations but on the contrary, they will only use bare hand to conduct the activities for short distance between workstations. Based on the observations from previous researches, most of the workers did not utilized any specific tools to handle the metal bar during transportation between the workstations. Figure 1.1 shows how the worker transports the long metal bar in industry.

Figure 1.1: Manual carrying of long metal bar

Manual handling is one of the crucial factors that may reflect on the major risk of injuries in the workplace. According to statistics record, Singapore's Ministry of Manpower released a report of 10,018 cases of workplace injuries for 2007. The major cause of these injuries are due to the manual handling activities and 53 % of the injuries

took place at manufacturing and construction sites. According to Shepherd (1970), the result of the study shows that 55 % of workers absent from work due to manual handling injuries such as back pain and other cumulative disorders. The causes of this injuries were mostly due to improper lifting techniques of materials.

It has been recognized that the existence of high risk for workers to perform the task of repetitive lifting or carrying objects in workplace. The situations are getting ever more critical when the workers are engaged with heavy loads in an awkward or bending postures. Manual handling is considered hazardous especially when the workers are engaging with a heavy or large size of the load. It is difficult for the workers to grasp the load which may cause load slipping. Work-related musculoskeletal disorders (MSDs) is known as the most general diseases caused by incorrect manual handling. It is most probably due to overexertion in lifting the object. According to US Bureau of Labor Statistics, a total of 356,910 cases of musculoskeletal disorders which are occupied 31 percent of the total cases for all private industry and local government workers in 2015. Due to the impact of the accidents or injuries, the average recovery period required for the private industry workers are around 12 days (Bureau, U. S. of Labor Statistics., 2015). As a result, the issues of losing working hours may reduce the work productivity of workers.

Most of the regulations agreed that the working environment should be get rid of manual handling activities in order to reduce the risk of occupational accidents. However, some of the tasks must be accomplished with the manual handling activities. As a result, mechanical aids like tool handles are required to eliminate or reduce the impact of such activities. Numerous case studies have indicated that workload and the risk of injuries can be reduced by utilizing a well-designed handling aids (Van der Molen *et al*., 2015). Certainly, the industry can find out the most suitable aids which fit with their working outcomes since there are a lot of solutions have been proposed in the societies. Nevertheless, handle design is the most inexpensive improvement to the design of the task compared to other modifications such as hoist and cranes. The workers can utilize the handle to assist the task of lifting and carrying the load over a distance.

Multiple guidelines and researches on manual handling have been established to assist industrial practitioners to minimize occupational health risk and work efficiency in lifting and carrying long metal bars. However, the previous studies are focussing on the motorized equipment design (Bassily *et al*., 2007) and development of manual materials