Faculty of Manufacturing Engineering

THE EFFECT OF ASSEMBLY DESIGN PARAMETERS ON ASSEMBLY TIME

Precilla Anak Sylvester Sabuk

Master of Science in Manufacturing Engineering

2015

THE EFFECT OF ASSEMBLY DESIGN PARAMETERS ON ASSEMBLY TIME

PRECILLA ANAK SYLVESTER SABUK

A thesis submitted
in fulfillment of the requirements for the degree of Master of Science
in Manufacturing Engineering

Faculty of Manufacturing Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

DECLARATION

I declare that this thesis entitle "The effect of assembly design parameters on assembly time" is the result of my own research except as cited in the references. The thesis has not been accepted for any master and is not concurrently submitted in candidature of any other master.

Signature : .....

Name : Precilla Anak Sylvester Sabuk

Date : .....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Manufacturing Engineering.

Signature :.....

Supervisor Name :.....

Date : .....

DEDICATION

To my beloved father and mother

ABSTRACT

Reducing cycle time has an impact in many aspects such as productivity and capacity of industry. There are many factors affect the cycle time, among them are workstation or workplace design, tools, operators and working conditions. The lesser is the time to produce product, the higher the productivity. The effect of assembly design parameters such as workstation design, working posture: standing and sitting and jig design on plug assembly time were studied in this thesis. The gender was also included as one factor to investigate in this study. The parameters or factors involved were three jig designs i.e. rectangular, horizontal and vertical; number of holders per jig: three, four, five holders and working postures: standing and sitting to assembly time. The study also explores the model relationship of all main factors and their interactions. A full factorial design of experiments of four factors with 2 and 3 levels was introduced. Ten participants consisting of five males and fives females were asked to assemble the plugs (model BS 1363). Each participant had to perform 10 replications for each 18 different set of experiment. The assembly time was recorded upon the completion of plug assembly task for each jig setting. This experiment recorded 3600 observations. The study concluded that all main factors, two and three way interaction factors significantly contributed to assembly time. The lowest assembly time for jig design setting is the rectangular jig with 3 holders per jig in the sitting posture by male operators. Meanwhile the highest assembly time was the 5 plugs holder per jig with horizontal shapes in standing posture which was performed by the female operator. The study also generates the regression model that describes the relationship of all factors involved. Validation of the model also was performed by taking some runs of experiments. The average deviation of actual data and predicted is less than five per cent.

ABSTRAK

Mengurangkan masa kitaran mempunyai kesan dalam pelbagai aspek seperti produktiviti dan kapasiti industri. Terdapat banyak faktor mempengaruhi masa kitaran, di antara mereka ada stesen kerja atau tempat kerja reka bentuk, alat, pengendali dan kondisi. Apabila masa semakin berkurang untuk menghasilkan produk, produktivitinya juga adalah semakin tinggi. Kesan parameter reka bentuk pemasangan seperti reka bentuk stesen kerja, postur kerja: berdiri dan duduk dan reka bentuk jig pada masa pemasangan plug dibincangkan di dalam tesis ini. Jantina juga dimasukkan sebagai salah satu faktor yang terlibat dalam kajian ini. Parameter atau faktor-faktor yang terlibat adalah tiga reka bentuk jig iaitu segi empat tepat, mendatar dan menegak; kuantiti pemegang untuk setiap plug: tiga, empat, lima dan postur berkerja: berdiri dan duduk semasa pemasangan plug. Kajian ini turut mengenal hubungan model semua faktor-faktor utama dan saling interaksinya. Satu reka bentuk ujikaji faktorial penuh bagi ke empat faktor tersebut melibatkan 2 dan 3 level. Sepuluh peserta yang terdiri daripada lima lelaki dan lima perempuan diminta untuk memasang plug (model BS 1363). Setiap peserta perlu melaksanakan 10 replikasi untuk setiap 18 set eksperimen. Masa pemasangan direkodkan setelah tamat tugas pemasangan plug bagi tetapan setiap jig. Eksperimen ini merekodkan sebanyak 3600 pemerhatian. Kajian ini menyimpulkan bahawa semua faktor-faktor utama dan kira dua dan tiga faktor interaksi adalah ketara menyumbang ke semasa pemasangan. Masa perhimpunan paling rendah untuk tetapan reka bentuk jig adalah segi empat tepat, 3 pemegang setiap plug, postur duduk oleh pengendali lelaki. Sementara itu yang paling tinggi adalah masa pemasangan adalah nombor 5 pemegang setiap plug dengan reka bentuk mendatar dalam postur berdiri yang dilakukan oleh pengendali perempuan. Kajian ini juga menjana model regresi yang menerangkan hubungan semua faktor yang terlibat. Pengesahan model yang juga dilakukan dengan mengambil beberapa larian eksperimen. Sisihan purata data sebenar dengan kurang daripada lima peratus.

ACKNOWLEDGEMENT

First and foremost, I offer my sincere gratitude to my supervisor, Prof. Dr. Adi Saptari, who has supported me throughout my thesis with his patience and knowledge. I attribute the level of my Master degree to his encouragement and effort and without him, this thesis would not have been completed or written.

I am as well indebted to Universiti Teknikal Malaysia Melaka (UTeM) for their assistance and funding in supplying relevant equipment for my research.

I would like also thanks to the partcipants of my research, without them this work may not be finished.

Last but not least, I would like to thanks my parents for their unconditional support, both financially and emotionally throughout my master. In particular, the patience and understanding shown by my dad, mum and siblings throughout my studies are greatly appreciated.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

ANOVA - Analysis of Variance

BMI - Body Mass Index

CADWORK- Computer Aided Design of Workplace

DF - Degree of freedom

DOE - Design of experiment

E&E - Electrical and electronics

FFCSA - Fat Free Cross Sectional Area

GDP - Gross Domestic Product

LFPR - Labour Force Participation Rate

MS - Mean Square

MSDs - Musculoskeletal Disorder

OFAT - One Factor at a Time

PCA - Printed Circuit Assembly

REBA - Rapid Entire Body Assessment

RSIs - Repetitive Strain Injury

RULA - Rapid Upper Limbs Assessment

SS - Sum of Squares

VV - Varicose Veins

ZCR - Zones of convenient reach

LIST OF PUBLICATIONS

A. Saptari, A., P. S. Sabuk, I. Halim, E. Mohammad, M.R. Salleh, Effect of Assembly Design Parameters on Assembly Time, *Journal of Advanced Manufacturing Technology*, 2015. (in progress).

CHAPTER 1

INTRODUCTION

1.0 Background

Manufacturing is an important sector in Malaysia. Besides agriculture, Malaysia manufacturing sector is also labour intensive and was considered a high yield investment opportunity. The country's economic development driven by export oriented manufacturing sector makes Malaysia a top choice for foreign direct investment.

This unprecedented rapid economic growth for Malaysia has been accompanied by a marked structural transformation of the Malaysian economy. In 2012, the manufacturing sector alone, SMEs constituted 20.6 per cent (RM 186.7 billion) to total manufacturing output. Today, the manufacturing industry continues to develop rapidly and has since become an important catalyst to country's economic growth (Economic Planning Unit, 2012).

The electrical and electronics (E & E) industry are one of the leading industries, contributing 24.5 per cent to the manufacturing sector in Malaysia's Gross Domestic Product (GDP). E&E products have been the largest traded items in Malaysia for several decades since the industry inception in the 1960s. The industry evolution until today has turned Malaysia as one of the leading points in the global E&E value chain (Malaysia External Trade Development Corporation, 2014).

In 2012, Malaysia's exports of E&E products was valued at RM 231.23 billion, with 49.2 per cent share of manufactured goods exports and 32.9 per cent share of Malaysia's total exports. E&E products were also the largest imports amounted to RM175 billion, representing a share of 37.8% of manufactured goods imports and 28.8% of Malaysia's total imports (Malaysia External Trade Development Corporation, 2014).

Moving up the value chain was crucial to ensure long term competitiveness of Malaysia. Gartner (2009) reports that both Singapore and Malaysia continue to develop a highly educated workforce, equipped with strong knowledge, creativity and innovation and are moving up the value chain into higher value added electronic production. These key determinants are crucial for the two close neighbours to ensure their long terms competitiveness in the electronic industry.

The assembly in E&E industry is exposed to high level of competition. Margins are low is the reason of why it becomes vital to reduce waste in order to stay competitive also to be able to deliver just in time with short notices. In lean manufacturing, the wastes are defined as anything which does not add value to the end product. These waste categorized are over production, waiting, including time in queue, work in progress (WIP), transportation between workstation or between supplier and customers, inappropriate processing, excess motion or ergonomic problems, defected product and underutilization of employees (Fawaz, 2003).

This concept of reducing waste in industry appears to hold considerable promise for addressing a range of simultaneously, competitive demands including high levels of process and product quality, low cost and reductions in lead times. As waste is eliminated,

the quality was improved while production time and cost are reduced (Sakthidhasan and Vendan, 2010).

In today competitive business world, companies require short lead times and low costs of products. Because of this, company have been putting in significant effort to reduce the cycle time and increase productivity according to Gaither (1994). Organizations have focused on cycle time as a productivity measure which can reduce the delivery time and improve the quality, thereby creating more satisfied customer. Cycle time or lead time is from the time a customer release an order until the time they receive the finished product. As the Japanese example of just-in-time-production has shown, reducing lead times may increase productivity and improve the competitive position of the company.

Manual assembly line types industries are still dominate in Malaysia E&E industries. There are many aspects that affect the performance in assembly process. Among others are workstations design, work methods and equipment such as jig, tools and machine (Lin and Chan, (2006); Shikdar and Al-Hadhrami, (2007); Yeow and Nath, (2003); Lai and Saptari, 2011). The workstation design among others associated to the standing or sitting position and the height of a table. Work methods in assembly are linked to the combination of number of workers and the equipment used. Equipment or a tool help workers in accuracy as well as increasing the cycle time in work. One of the common tools used for assembly is a jig.

1.1 Problem Statements

Reducing cycle time as previously mentioned has impact in many aspects in production such as productivity and capacity of industry. The lesser is the time to produce product, the higher the productivity. There are many factors affect the cycle time, among them are workstation or workplace design, tools, operators and working conditions.

Workstation design in this study refers to design of work place that can improve the fits between human and machine environment that may increase productivity, safety, and reduce human error (Wickens et al., 2004). Human anthropometry knowledge in relation with the machine dimensions became the key elements in workstation design There are various studies on improving the operator's productivity (reduce assembly cycle time) in assembly line through ergonomics approaches. Previous researcher has investigated on how to reduce the assembly cycle time in a semiconductor company. Yeow and Nath (2003) proposed an ergonomic intervention by improving workstation design. The improvement had significantly contributed the assembly cycle time in the company and eventually contribute to better productivity and reduction of cost. Battini et al. (2011) proposed method on how to integrate ergonomics and assembly design to improve productivity of assembly system.

The study conducted by Saptari et al. (2007) on assembly design showed that jig provides significant contribution to assembly time. The jig created in the research has four numbers of holders with horizontal shape. Furthermore, Lai and Saptari (2011), improved the design of assembly by studying the effect of number of workers, different design of jigs and different position of working to assembly time or cycle time. It concluded that these factors had an effect on assembly time.

On the working posture i.e. standing or sitting influence operator work's performance. Halim et al. (2012) pointed out that prolonged standing leads to muscular fatigue in lower extremities, such as lower back, posterior leg and anterior leg due to static contraction. In a long run, these discomforts and muscular fatigue can lead occupational disorders and adversely impact the workers' health and efficiently at work. A seated workplace should be used for long duration tasks whenever it is possible, as it is easier to maintain a seated posture and the strain imposed on the body is much lesser compared to standing posture (Wickens et al., 2004).

Operators in industry nowadays are no longer dominated by male. Female Labour Forced Participation Rate (LFPR) has increase 1.6% in period 2011 to 2012 from 47.9 to 49.5%. Male and female physically are different, and due to that there are certain kind of job where male is more dominant than female and vice versa (Economic Planning Unit, 2012). MacDermid et al. (2002) found that gender was inconsistently related to dexterity times, but women tended to be faster than men in multitasking. Furthermore, it was found that on average males are stronger than females. It is generally thought that this is because males have greater muscle bulk. Due to a larger amount of contractile tissue, greater muscle bulk results in greater strength, providing that the architecture of the muscle fibres within the muscles being compared is similar.

This research focused to investigate how assembly design variables such as workstation design, working posture, jig design and gender effect on assembly time. Finding the best combination of set of parameters, that would provide the lowest assembly time which would be beneficial to industry.

1.2 Objectives

1. To investigate the effect of different assembly designs of jig and working posture on plug assembly time.

2. To investigate whether there are any significant differences on workers performance based on gender.

3. To model the relationship between the various design parameters and on the plug assembly time.

1.3 Significance of study

This study will be a significant endeavour in E&E (electronic and electric) industry especially in manual assembly line. E&E is the largest manufacturing sub-section in term of GDP contribution. Therefore, research in design of assembly may help to increase the efficiency in electronic industry, and also to achieve the lowest assembly time in order to meet the expected increase in customer demand.

The design for assembly has received much attention in recent years because operations constitute a high labour cost for many manufacturing companies. One of the key successful factors for design of assembly can be stated as an assembly that may produce the lowest assembly time.