Faculty of Manufacturing Engineering

THE EFFECT OF WORKING CONDITIONS AND GENDER ON HUMAN ERRORS IN MANUAL ASSEMBLY LINE

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DECLARATION

I declare that this thesis entitled "The Effect of Working Conditions and Gender on Human Errors in Manual Assembly Line" is the result of my own research except as cited in the references. This thesis has not been accepted for any degrees and is not concurrently submitted in candidature of any other degree.

Signature :……...

Name :……..

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 :……..

ABSTRACT

Product defects in an assembly line can happen due to various reasons, and one of the sources is human error. The occurrence of human errors in manual assembly line can be affected by factors, such as workplace condition/environment, equipment and demographics factors. This study adopted two approaches i.e. lab experiment and case study in industry. In the first part, a three-pin plug assembly line was used to simulate the production. The experiment was conducted in the lab to determine the effect of work pace, working conditions, such as working position, jig design, and component bin position, and gender on human errors during manual assembly. The product defects were identified as the occurrence of nonconformance product due to human error. To minimize the sources of defect from other factors, such as working environment, material defects, working experience and equipment failures, these factors were controlled in the experiments to ensure that the defects obtained were solely due to human error. A total of ten participants had participated in this experiment, five adult males and five females. A full-factorial design of experiment was used and there were sixteen combinations of experimental runs in this research. Results showed that there was a linear correlation between work pace and human error. When the production pace increased over the normal, cycle time decreases, causing time pressure condition which had significant effect on human error. Working position had the second greatest effect on human error, followed by gender difference and component bin position. Jig design had no significant effect on human error. Gender difference contributed to the differences in human errors, where females made fewer errors than males in normal pace as well as in the time pressure environment. However, male had faster cycle time than female. Finally, a fitted model which can describe the relationship between human error and working condition parameters was proposed and validated. This model functions as the predictor of human error when the variables of assembly are known. In the second part, a case study was conducted in an electronic company located in Melaka, Malaysia. This company uses an assembly line to produce their products. The case study only focused on the effect of work pace on the occurrence of human errors that lead to product defects. The other variables, such as working position, component bin position, jig design and gender, were not included as they were not applicable in the workplace of the case study. Based on the results, it was observed that the occurrence of human error was higher when production target is increase above the normal capacity. This situation was recognized that there was a time pressure to the workers. In addition, the number of errors also increased as the production target lower than the normal production capacity. The relationship of product defects and production output can be represented using a U-model, where the number of product defects was higher when the production output was lower or higher than the normal production target. This finding was consistent with the experimental results, where time pressure affects the occurrence of human errors.

ABSTRAK

Kecacatan produk dalam barisan pemasangan boleh berlaku atas pengaruh pelbagai sebab, dan salah satu sebab tersebut adalah kesilapan manusia. Kesilapan manusia boleh dipengaruhi oleh faktor-faktor seperti persekitaran tempat kerja, peralatan yang diguna dan faktor-faktor demografi. Kajian ini melibatkan dua kaedah penyelidikan yang berbeza, iaitu eksperimen dalam makmal dan kajian kes dalam industri. Bagi kaedah eksperimen, satu eksperimen yang melibatkan pemasangan plug tiga pin telah dijalankan. Eksperimen tersebut dijalani dalam makmal untuk menentukan kesan kadar kerja, posisi kerja, rekabentuk jig, posisi bekas komponen dan jantina pada kesilapan manusia semasa pemasangan manual. Kecacatan produk disebabkan kesilapan manusia merupakan fokus utama dalam kajian ini. Oleh itu, pengaruh faktor-faktor lain yang boleh menyebabkan kecacatan produk, seperti faktor persekitaran, kecacatan bahan, pengalaman bekerja dan kegagalan peralatan, telah dikawal. Sepuluh orang peserta yang terdiri daripada lima lelaki dan lima perempuan telah mengambil bahagian dalam eksperimen ini. Full-factorial design *digunakan, dan terdapat enam belas kombinasi dalam eksperimen ini. Hasil kajian menunjukkan bahawa terdapat korelasi linear di antara kadar kerja dan kesilapan manusia. Apabila sasaran pengeluaran meningkat, kitaran masa akan berkurangan dan ini menyebabkan situasi tekanan masa yang mempunyai kesan paling ketara pada kesilapan manusia. Posisi kerja adalah faktor kedua yang mempunyai kesan ketara atas kesilapan manusia, diikuti oleh jantina dan posisi bekas komponen. Rekabentuk jig tidak ada kesan yang ketara pada kesilapan manusia. Perbezaan jantina menunjukkan bahawa lelaki melakukan lebih banyak kesilapan berbanding perempuan, tetapi, lelaki menggunakan masa yang lebih singkat untuk menyempurnakan kerja pemasangan. Satu model yang boleh menggambarkan hubungan antara faktor-faktor kajian dan kesilapan manusia telah dibina. Bagi kaedah kedua, satu kajian kes telah dilaksanakan di sebuah syarikat elektronik di Melaka, Malaysia. Syarikat tersebut mengguna barisan pemasangan dalam pemasangan produk. Kajian kes ini menumpu pada kesan kadar kerja atas kecacatan produk yang berlaku disebabkan kesilapan manusia. Kesan faktor-faktor lain, seperti posisi kerja, posisi bekas komponen, rekabentuk jig dan jantina, tidak dipertimbangkan kerana factor-faktor tersebut tidak sesuai dengan keadaan industry tersebut. Berdasarkan hasil analisis, kesilapan manusia meningkat apabila kadar pengeluaran melebihi sasaran pengeluaran biasa. Situasi ini menyebabkan tekanan masa pada pekerja-pekerja syarikat tersebut. Kesilapan manusia juga meningkat apabila kadar pengeluaran kurang daripada sasaran pengeluaran biasa. Hubungan antara kecacatan produk dan output pengeluaran boleh diwakili dengan U-model, di mana bilangan kecacatan produk meningkat apabila output pengualaran adalah lebih rendah atau lebih tinggi daripada sasaran pengeluaran biasa. Penemuan ini adalah konsisten dengan hasil kajian eksperimen; keadaan tekanan masa boleh meningkatkan kejadian kesilapan manusia.*

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LIST OF ABBREVIATIONS

Adj MS	-	Adjusted Mean Square
Adj SS	-	Adjusted Sum of Squares
ANOVA	-	Analysis of Variance
Coef	-	Coefficient
df	-	Degree of Freedom
DOSH	-	Department of Safety and Health
GEMS	-	Generic-error Modeling System
LED	-	Light-emitting Diode
Max	-	Maximum
Min	-	Minimum
QC	-	Quality control
R-Sq	-	R-squared
R-Sq (pred)	-	Predicted R-squared
R-Sq (adj)	-	Adjusted R-squared
R4 jig	-	Rectangular-shaped jig with 4 plug holders
RULA	-	Rapid Upper Limb Assessment
SE Coef	-	Standard Error of Coefficient
Seq SS	-	Sequential Sum of Squares
Std. Dev.	-	Standard Deviation
V3 jig	-	Vertical-shaped jig with 3 plug holders
Var		Variance

CHAPTER 1

INTRODUCTION

1.1 Background

Manufacturing industry plays a vital role in the development and growth of Malaysian economy (Karim et al., 2008). Manufacturing industry has been identified to be one of the most prominent economic backbones in Malaysia and the development of manufacturing industry has produced positive impacts to the economy of the country.

The electrical and electronics manufacturing industry plays a significant contribution to the Malaysian economy as it dominates the largest percentage in the nation's total exports, which is approximately 59.1% of the total manufactured exports. Although manufacturing technology in Malaysia is advanced, the electrical and electronic industry is still dominated by assembly operations (Malaysian Investment Development Authority (MIDA), 2012). Assembly line is one of the main components in manufacturing system. An assembly line allows the product to be assembled part by part, and at the same time, reduce the assembly cycle time of each individual and lower the inventory and direct cost (Heizer, 1998). As a result, companies can manufacture and supply high volume of products at a cheaper price.

Among the important factors in the manufacturing industry are worker's productivity and product quality. Quality can be defined in many ways, and usually, quality is related to one or more characteristics that a product should possess. The definitions of quality which are widely accepted include "fitness for use" and

"conformance to requirements" (Dhafr et al., 2006). Hence, the quality of a product implies the elimination of any type of defects from the product. A defect can be described as a deviation from the intended specification which is severe enough to affect the safety or usefulness of the product (Escalante, 1999). A defect is caused by an error. There are various possible sources of errors in assembly line, among others are human/operator's fault, equipment failure, and design mistakes.

There are various defects that have been determined in the past, for instance, omitted processing, processing error, missing parts, wrong parts, errors in setting up workpieces, equipment failures and others (Escalante, 1999). An assembly defect is the defect that happens during assembly processes. There are various factors which can lead to assembly defects, and these factors can be categorized into improper design, defective part, variation in assembly system and operator mistake (Su et al., 2010). Assembly defects do not only affect product quality, they also reduce company's profit margin as defective products need to be repaired, reworked and/or scrapped.

The implementation of advanced technologies in manufacturing sector has significantly improved productivity and efficiency, but assembly defects still cannot be eliminated completely. One of the reasons is due to the occurrence of human errors in the manufacturing/assembly processes. This is because the overall manufacturing system performance still depends on the instructions and decisions made by human operators (Koskinen et al., 2010). In addition, tasks which cannot be automated such as assembly and manual component insertions are still performed by human operators (Yeow and Nath Sen, 2006). Hence, this shows that the contribution of human being in assembly defects shall not be underestimated nor ignored.

The occurrence of human errors can be influenced by various factors, ranging from individual factors to physical environment factors (Baines et al., 2005). Boredom is one of the causes of human error, and assembly tasks are often categorized as highly repetitive, boring and tiring. Previous study also proves that time pressure is one of the causes of human error (Yang et al., 2010). Sometimes, workers in the manufacturing industry are subjected to time pressure due to large volume of customer orders. People who experience time pressure are usually in a stressful state and most of the time, the performance under this condition is poor. However, in some conditions, time pressure can enhance one's performance (Chong et al., 2011).

Different job environments require workers to perform the job assigned with different working position, either standing or sitting. Standing posture is often used in tasks where workers are required to make frequent movements, handle large and/or heavy objects or exert large forces with their hands; while seated posture is suitable for tasks which require high visual demands and frequent hand movements (Sanders and McCormick, 1993; Wickens et al., 2004). Maintaining the same working position for a prolonged period can affect one's productivity and physiological aspects. However, the effect of working positions on human error in assembly tasks has yet to be addressed.

Globalization has pressured manufacturers to shorten the product cycle time in order to sustain in this competitive market. One of the method to reduce assembly cycle time is through job aid such as jig. Saptari et al. (2007) noticed that assembly task can be completed faster with the help of jig, especially in plug assembly. Besides that, the design of the jig also significantly influences the assembly cycle time (Saptari et al., 2011). The usage of jig has successfully reduced assembly cycle time but the effects of cycle time reduction on human error are still unknown.

The setting/design of a workstation plays an important role in ensuring the comfort of the workers. A suitable workstation design allows workers to perform their work with good postures and subsequently reduce the cycle time for assembly process (Saptari et al., 2011). In most assembly workstation, component bins are placed flat on the workstation. However, placing the component bin with a tilt angle allows worker to retrieve the components from the bin easily. Tilted component bin placement may be beneficial in reducing assembly cycle time, but its effect on human error has yet to be addressed.

1.2 Problem statement

Human beings are prone to making errors due to various reasons and subsequently, this can lead to product defects and even occurrence of undesired incidents or accidents (Liu et al., 2009). Human error has been proven to be one of the major causes of assembly defects in the manufacturing industry (Su et al., 2010). The common assembly defects due to human error include wrong part and missing component. There are various factors which can contribute to the occurrence of human errors in a workplace, including environmental factors, physiological and psychological factors, and organization factors (Baines et al., 2005).

In this study, working conditions were referring to the variables in the workplace which can affect the performance, whilst work settings were defined as the different combinations of working conditions. Different work settings may influence the performance of human operator during assembly process. Saptari et al. (2011) had conducted a study to investigate the effect of jig design, workstation design and assembly line design on plug assembly time. Their research aimed to identify which work setting can

result in shortest assembly time in plug assembly. However, they did not consider the product quality or human error made during the assembly process.

There are various studies on improving the operator's productivity (reduce assembly cycle time) in assembly line through ergonomics approaches. However, there appears to be limited studies on how different working conditions can influence human error in assembly process. Hence, the aforementioned problems motivate the study on the following research question:

"How do working conditions including work pace, working position, component bin position and jig design influence the occurrence of human error in a workplace?"

1.3 Objectives:

The objectives of this study are as follow:

1) To determine the effect of working conditions and gender on human error in manual assembly line.
2) To develop a regression model that describes the relationship between working conditions and human error in manual assembly line.
3) To relate the findings of the model with the real occurrence in the industry.

1.4 Scope of study

This research focused on the influence of working conditions such as work pace, working position, component bin position and jig design on the occurrence of human errors in assembly process. In addition, the effect of gender difference on human error was also investigated. Human error was measured based on the number of assembly defects detected. This research involved two methods, which were lab experiment and industrial

case study. The defects due to human error were recorded. The examples of defects recorded include missing components, wrong part insertion, gap between the plug covers and poor joining. The other sources in the manufacturing processes were not considered.

In order to eliminate the effect of environmental factors, the working conditions for both the lab experiment and case study were ensured to comply with regulations under Factories and Machinery Act 1967, as stated by the Department of Occupational, Safety and Health (DOSH) in Malaysia. The level of illumination of work should be more than five-foot-candle (53.52 Lux), while the indoor temperature should be maintained between 20℃ and 24℃ . The maximum noise level for continuous noise exposure is below 90db, while the maximum impulse noise exposure shall not exceed 115db.

Besides environmental factors, equipment failure is also one of the contributors to human error in a workplace (Jo and Park, 2003). Hence, in order to exclude the contribution of this factor in this research, the frequency of maintenance and calibration of equipment used in the assembly processes need to be taken into consideration. In addition, assembly defects due to poor material/material defects were excluded by conducting screening for incoming materials. Other sources of errors associated with working conditions related to management, such as remuneration and benefits of workers, were not considered in this study.

Finally, human workers play a significant role in the assembly task. New workers or workers with no prior experience in the task performed tend to make mistake more often than those with experience (Wickens et al., 2004). It is important to provide necessary training to the workers to ensure that they possess all the required skills.

1.5 Significance of study

The importance of this research is to investigate the factors which can affect the occurrence of human errors in assembly line as an effort to reduce product defect rate. This study will contribute to better design of assembly processes which in turns results in better product quality and lower production cost. Any product defect in the assembly line is actually a cost to the company, as the defective product needs to be repaired, reworked or scrapped. These processes require additional time and labour which increases the production cost.

Electronic and electrical manufactured products play a significant role in the total nation exports. Hence, it is important for the electronic and electrical industry to produce products with good quality and in high volume to satisfy the global demands. The advancement of technology has improved the reliability of machineries and tools used in the manufacturing industry, leaving human being to be the least reliable component in a manufacturing system. Indentifying the variables which can affect human's reliability in a manufacturing system can help to reduce assembly defects caused by human beings and also the occurrence of industrial injuries and accidents.

Besides that, 10th Malaysia Plan (budget planning for 2011 until 2015) mentioned that the labour productivity growth in Malaysia is falling back. This may be due to the occurrence of defects, misfortunes and mishaps in the workplace. The reduction of productivity may be the effect of human error and workplace accidents. Hence, this research supports the 10th Malaysia Plan by determining the variables affecting the occurrence of human error in a manual assembly line, which can subsequently reduce product defect rate caused by human beings.

1.6 Organization of study

This thesis consists of six chapters, namely introduction, literature review, methodology, results and discussions, case study and conclusion.

Chapter 1 includes a brief introduction on the background of Malaysia's manufacturing industry is discussed and the problem statement is proposed. The main objectives of this study are discussed and the significance of this study is also being related to the 10th Malaysian Plan.

Chapter 2 focuses on the literature of the variables in this research. The literature review discusses on the variables which influence human error in production assembly line. These variables include work pace, working position, component bin position and jig design. The literatures on the types of human error are also included. Furthermore, this chapter will also include the gap of the study.

Chapter 3 discusses the methods used to conduct this research. There are two research methods involved, namely lab experiment and case study. For the lab experiment, an experiment is designed using 2×2×2×2 full factorial design and the hypotheses for this research are proposed. On the other hand, the case study is conducted in real-life industry and the results obtained will be compared with the results of lab experiment.

Chapter 4 presents the results and discussions of the statistical data analyses. In this chapter, the data collected are analyzed and the effects of the independent variables on human error are identified and discussed. In addition, the acceptance and rejection of the proposed hypotheses are also shown in this chapter.

Chapter 5 focuses on an industrial case study conducted in an electronic company in Malaysia. This case study discusses on the industrial practices and analyses on the human error collected. The findings of this case study are compared with the experimental results.