Faculty of Manufacturing Engineering

OPTIMUM CYCLE TIME BASED ON JIG AND WORKSTATION DESIGN COMBINATIONS

Nabilah binti Mohd Safar

Master of Manufacturing Engineering (Industrial Engineering)

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NABILAH BINTI MOHD SAFAR

A master project report submitted
As a partial fulfillment of the requirements for the degree of Master of Manufacturing Engineering (Industrial Engineering)

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2010

DECLARATION

I hereby, declared this master project report entitled "Optimum Cycle Time Based on Jig and Workstation Design Combinations" is the result of my own research except as cited in references.

Signature : .....

Author's Name : NABILAH BT MOHD SAFAR

Date : 22/07/10

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfilment of the requirements for the degree of Master in Manufacturing Engineering (Industrial Engineering). The member of the supervisory committee is as follow:

(Signature of Supervisor)

.....

(Official Stamp of Supervisor)

PROF. MADYA DR. ADI SAPTARI
Ketua Jabatan (Pengurusan Pembuatan)
Fakulti Kejuruteraan Pembuatan
Universiti Teknikal Malaysia Melaka
Karung Berkunci 1200, Hang Tuah Jaya,
Ayer Keroh, 75450 Melaka

ABSTRACT

Jig design and workstation design are areas that influence productivity. Good combination of jig and workstation design is needed to obtain optimum cycle time. The best combination also helps workers to perform their job faster and easier and thus, enhance the productivity. This project determines the most significant combination of jig design and workstation design in assembly line of plug. The first step of the study was to determine the factors that influence the productivity; in this case they were the assembly time of electrical appliances which are BS 1363 plugs. The second step was to determine the level of each factor and then design for full factorial experiments. There were three factors being evaluated for their influence on assembly time of plug i.e. number of plug per jig, shape of jig and assembly position of worker. Number of plug per jig factor has three levels (3, 4 and 5), shape of jig factor has 3 levels (horizontal, vertical and square) and assembly position has two levels (sitting and standing). There were eighteen combinations of experimental runs and each combination was repeated eight times. Therefore, total of 144 experiments were conducted for this project. ANOVA was used to identify the optimum combination. The result shows that the lowest average of assembly time is obtained at combination of five plugs per jig, square jig shape and sitting position.

ABSTRAK

Rekabentuk jig dan ruang kerja adalah aspek-aspek yang mempengaruhi produktiviti. Kombinasi rekabentuk jig dan ruang kerja yang baik diperlukan untuk mencapai kitaran masa yang optima. Kombinasi yang terbaik juga membantu pekerja menjalankan kerja dengan pantas dan mudah dan seterusnya, meningkatkan produktiviti. Projek ini menentukan kombinasi rekabentuk jig dan ruang kerja yang paling penting di dalam pemasangan palam. Langkah pertama ialah mengenalpasti faktor-faktor yang mempengaruhi produktiviti; dalam kes ini adalah masa pemasangan peralatan elektrik palam BS 1363. Langkah kedua pula ialah mengenalpasti tahap untuk setiap faktor dan kemudian membentuk eksperimen faktorial penuh. Terdapat tiga faktor yang dikesan dapat mempengaruhi masa pemasangan palam. Faktor-faktor tersebut adalah bilangan palam untuk satu jig, bentuk jig dan posisi pekerja ketika pemasangan. Bilangan palam untuk satu jig mempunyai tiga tahap (3, 4 dan 5), bentuk jig juga mempunyai tiga tahap (melintang, menegak dan segi empat sama) dan posisi pemasangan mempunyai dua tahap (duduk dan berdiri). Terdapat lapan belas kombinasi dalam eksperimen ini dan setiap kombinasi diulang eksperimen sebanyak lapan kali. Maka, jumlah eksperimen yang dijalankan dalam projek ini adalah sebanyak 144 eksperimen. ANOVA telah digunakan untuk mengenalpasti kombinasi yang optima. Keputusan menunjukkan purata masa pemasangan yang terendah adalah bagi kombunasi lima palam untuk satu jig, bentuk segi empat sama dan posisi duduk.

DEDICATION

For my beloved mother

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DOE	-	Design of Experiments
ANOVA	-	Analysis of Variance

CHAPTER 1

INTRODUCTION

This chapter contains the background, problem statement, objectives and scope of the project. The background gives an overview of the importance of proper jig design in an assembly line. Meanwhile, the problem statement discusses problem regarding jig and workstation designs in plug assembly line. The objectives and scope are defined based on the problem statement.

1.1 Background

Equipment design is one of the major areas in which the productivity may be improved. Jig is one of the common equipment used in manufacturing or assembly line. It is a special tool to locate and firmly hold work piece in desired position during operation.

Besides equipment design, another important area is workstation design. Workstation is one of a series of workplaces that may be occupied or used by the same person sequentially when performing a job. It may also be a location where a person performs a task for short durations, such as assembling or monitoring. Workstation should be designed so that most people can safely and effectively perform the required tasks.

An assembly line is a manufacturing process in which parts are added to a product in a sequential manner using optimally planned logistics to create a finished product much faster than with handcrafting-type methods. A proper jig design and workstation design can increase the productivity of an assembly line by improving the workers' performance in term of speed and capability. If the jig or workstation design is not suitable, the operator may feel uncomfortable and thus, cannot perform assembly task with good performance.

There are several parameters to determine the proper jig and workstation designs. Among the parameters are the number of plug per jig, shape of jig, and assembly position of worker. These parameters determine the operators' performance such as the productivity of assembly process.

$$Productivity = \frac{assembly\ time}{number\ of\ product\ produced}$$

To investigate which parameters determine the performance of workers, design of experiments may be used to help researchers find the best setting. Design of experiments is widely used in research and development, where a large proportion of the resources go towards solving optimization problems. It is a strategy approach to gather empirical knowledge, i.e. knowledge based on the analysis of experimental data and not on theoretical models. Commonly, it is applied when intend to investigate a phenomenon in order to gain understanding or improve performance.

This research is an attempt to determine optimum cycle time based on jig and workstation designs combinations by using full factorial design of experiments.

1.2 Problem Statement

Today's plug assembly companies used different combinations of jig design and workstation design for plug assembly. The cycle time of plug assembly process for each company is varied as different types of jig design and workstation design influence the cycle time.

Good design of jig and workstation can reduce the cycle time of the plug assembly process. Therefore, significant factors in jig design and workstation design need to be determined in order to help workers do their job faster and easier.

1.3 Objectives

The aims of this research are:

(a) To identify factors and levels of design of experiments on plug assembly line.

(b) To find significant factors that determine the optimum cycle time in plug assembly line.

1.4 Scope and Limitation

This research is focusing on designs of jig and workstation for plug assembly line. Combinations of jig and workstation designs are analyzed by considering full factorial design

of experiments. Experiments are conducted in Manufacturing Engineering Laboratory of Universiti Teknikal Malaysia Melaka (UTeM). Different designs of jig used for the experiments are made by a researcher. Data is gathered based on electrical appliances which are BS 1363 plugs and different designs of jig. Subject (operator/worker) is trained to assemble plugs in total time of 2 hours until he/she is familiar with the assembly job to ensure constant performance during the experiments. The data is analyzed by using Minitab software.

CHAPTER 2

LITERATURE REVIEW

This chapter basically explains about jig design and workstation design based on information from journals, books and internet articles. Besides, this section also discusses the experimental program and other issues related to this project.

2.1 Introduction

Normally, an assembly task requires precise alignment and therefore, a reliable assembly tooling is needed so that the components can be hold in an accurate and repeatable position. It can also prevent undesired motion of components and avoid posing interference problems. Besides tooling, worker position while doing the assembly task is also important to prevent easy fatigue while doing repeated task.

One or more flexible or specific work holding devices can be used for repeated assembly process as great aids and time savers. Some commercial ones are available in the market and many can be made by using plywood, metal or plastic material.

Meanwhile, the goal of human factors is to design systems that reduce human error, increase productivity, and enhance safety and comfort. Workplace design is one of the

major areas in which human factors professionals can help improve the fit between humans and machines and environments.

In an engineering environment, experiments are often conducted to explore, estimate or confirm. Exploration refers to understanding the data from the process while estimation refers to determining the effects of process variables or factors on the output performance characteristic. Confirmation implies verifying the predicted results obtained from the experiment.

In manufacturing processes, the primary interest is often to explore the relationships between the key input process variables (or factors) and the output performance characteristics (or quality characteristics). For example, in a plug assembly line, types of jig can be treated as factors and productivity can be considered as performance characteristic.

Statistical thinking and statistical methods play an important role in planning, conducting, analyzing and interpreting data from engineering experiments. When several factors influence a certain characteristic of a product, the best strategy is to design an experiment so that valid, reliable and sound conclusions can be drawn effectively, efficiently and economically.

In a designed experiment, the engineer often makes deliberate changes in the input factors and then determines how the output functional performance varies accordingly. It is important to note that not all factors affect the performance in which some may have medium influences and some have no influence at all.

Therefore, the objective of a carefully planned designed experiment is to understand which set of variables in a process affects the performance most and then determine the best levels for these variables to obtain satisfactory output functional performance in products.

2.2 Jig Design

Work holder is the general term for a jig. The economical production of engineering components is greatly facilitated by the provision of jig. The origin of jig can be traced back to the Swiss watch and clock industry form in which, after proving their usefulness, they spread throughout the entire metalworking industry.

The use of a jig makes a fairly operation simpler which would otherwise require a lot of skill and time. A jig can position components accurately and hold rigid components besides prevent components movement during working in order to gain greater productivity for assembly line (Resnick, et al., 1997).

A jig is a type of fixture with means for positively guiding and supporting tools for assembly and related operations (Rajan, et al., 1999). Jig is a production tool used to accurate manufacture duplicate and interchangeable parts. Jig is specially designed so that a number of components can be machine or assembled identically in one batch to optimize time and energy and also to ensure interchangeability of components. It use is limited only by job requirements and the desire of the designer.

While using, a jig must be clean, undamaged and free from grit, which components must not be forced into the jig. Jigs are precision tools and therefore, some of them are

expensive to produce because they are made to fine limits from materials with good resistance to wear. These jigs must be properly stored or isolated to prevent accidental damage and numbered for identification for future use.

There are several analyses of jig design done by researchers that proved design of jig does relate to productivity. Kim, et al., (2002) has suggested a reliable technique to reduce error components by developing a system using a camera and an exclusive jig to precisely measure size of tool wear.

Meanwhile, Resnick, et al., (1997) has done an analysis to the effect of tool jig, work height and movement distance on performance time and Rajan, et al., (1999) has analyzed the design of floor assembly jigs and ensure assembly process does not pose accessibility and ergonomics problems.

2.3 Workstation Design

In most job environments, workers either stand or sit during work. Standing workplaces are usually used where the workers need to make frequent movements in a large work area, handle heavy or large objects, or exert large forces with their hands. Prolonged standing is a strainful posture that puts excessive load on the body and may lead to body fluid accumulation in the legs. Therefore, a worker should not be required to stand for long time without taking a break. Use of floor mats and shoes with cushioned soles may also help increase a standing worker's comfort.

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