Faculty of Manufacturing Engineering

CAPACITY PLANNING FOR MIXED-LOAD TESTER UNDER DEMAND AND TESTING TIME UNCERTAINTY

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Doctor of Philosophy

2018

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A thesis submitted
in fulfillment of the requirements for the degree of Doctor of Philosophy

Faculty of Manufacturing Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2018

DECLARATION

I declare that this thesis entitle "Capacity Planning for Mixed-Load Tester under Demand and Testing Time Uncertainty" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not currently submitted in candidature of any other degree.

Signature : ....

Name : Hayati Mukti Asih

Date : 3th August 2018

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 Doctor of Philosophy.

Signature	:	....
Supervisor Name	:	Prof. Dr. Chong Kuan Eng
Date	:	3th August 2018

DEDICATION

A special feeling gratitude to Allah SWT for the completion of my Ph.D. with a great blessing and experiences. I dedicate my work to my husband, son, beloved parents, and my sister. I am highly thankful and always appreciate the love, prayer, support, and consideration.

ABSTRACT

Capacity planning is an important decision in production planning as it determines the capacity to install in order to satisfy customer demands and also to allocate products to those capacities. This research is based on mixed-load machine problem which is categorized by multiple products that can be processed simultaneously with different processing time. The problem is further complicated with high product varieties and high demand variabilities. This research was conducted based on a case company from a multinational manufacturing company in Malaysia that produces hard disk drives. The study focused on the automated testing process characterized by long lead time and high product variability. Each testing machine with 2880 slots is a mixed load tester with the ability to load and test multiple product families simultaneously. In addition, the uncertain demand and testing time makes the problem more challenging. Currently, the company's issue is low tester utilization of about 71%, well below the target of 96%. The objective of this research is to improve tester utilization while achieving the production target under uncertain demand and testing time and also to determine the break-even point on the testers required. A novel approach of integrating a mathematical model, robust optimization model, genetic algorithm, simulation model and cost – volume – profit analysis was developed. Firstly, a mathematical model of mixed-load tester was formulated. Next, a set of discrete scenarios was proposed to address uncertain demand and testing time. A robust optimization and genetic algorithm model was developed to optimize the number of testers under the described uncertainties. Next, these scenarios were simulated using the ProModel simulation software to validate the proposed models and to evaluate throughput and tester utilization. Finally, the cost–volume–profit analysis was performed for scenarios that require additional testers at various levels of uncertainties. The results showed that the proposed solution improved tester utilization by 25% compared to the current system. This research has contribution by developing novel hybrid methodology and able to provide useful insights to assist company's managers to plan and allocate resources according to variations in customers' demands and testing time.

ABSTRAK

Perancangan kapasiti merupakan keputusan penting dalam perancangan pengeluaran kerana ianya menentukan keupayaan pemasangan dalam memenuhi permintaan pelanggan dan juga memperuntukkan produk kepada kapasiti tersebut. Penyelidikan ini berdasarkan masalah mesin bercampur yang dikategorikan berdasarkan kepelbagaian produk dan mampu diproses secara serentak dengan waktu pemprosesan yang berbeza. Permasalahan utama wujud apabila variasi dan permintaan terhadap produk semakin meningkat. Kajian ini dijalankan berdasarkan syarikat kes dari firma pembuatan multinasional di Malaysia yang menghasilkan pemacu cakera keras. Kajian ini memfokuskan terhadap proses ujian terautomasi yang bercirikan jangka masa panjang dan kebolehubahsuaian produk yang tinggi. Setiap mesin ujian dengan slot 2880 adalah penguji beban campuran dengan keupayaan untuk memuat dan menguji beberapa jenis produk pada masa yang sama. Di samping itu, permintaan dan masa ujian yang tidak menentu menjadikan masalah lebih mencabar. Isu syarikat sekarang adalah penggunaan penguji rendah yang dianggarkan 71%, iaitu jauh di bawah nilai sasaran 96%. Objektif penyelidikan ini adalah untuk meningkatkan penggunaan penguji semasa mencapai sasaran pengeluaran di dalam permintaan dan juga masa ujian yang tidak menentu disamping untuk menentukan titik pemecah pada penguji yang diperlukan. Pendekatan baru dibangunkan dengan mengintegrasi model matematik, model pengoptimuman yang mantap, algoritma genetik, model simulasi dan analisa keuntungan jumlah kos. Pertama, model matematik penguji beban campuran telah dirumuskan. Seterusnya, satu set senario diskret dicadangkan untuk menangani permintaan dan ketidaktentuan masa ujian. Model optimasi dan algoritma genetik telah dibangunkan untuk mengoptimumkan bilangan penguji di bawah ketidakpastian yang diterangkan. Seterusnya, senario ini disimulasikan dengan menggunakan perisian simulasi ProModel untuk pengesahan model yang dicadangkan dan untuk menilai aplikasi serta penggunaan penguji. Akhir sekali, analisis kos-isipadu kos dilakukan untuk senario yang memerlukan penguji tambahan di pelbagai peringkat ketidakpastian. Hasil analisis menunjukkan bahawa penyelesaian yang dicadangkan berupaya meningkatkan tahap penggunaan penguji sebanyak 25% berbanding dengan sistem sedia ada. Sumbangan kajian ini adalah dengan pembangunan model hybrid yang dapat memberi perspektif yang berguna kepada pengamal industri dalam peringkat merancang dan peruntukan sumber berdasarkan variasi permintaan pelanggan dan juga masa ujian.

ACKNOWLEDGEMENTS

In the name of Allah, The Beneficent, The Merciful.

Alhamdulillahi rabbil `alamin. All praise belongs to Allah, who by his blessing and mercy all righteous deeds are being perfected, and this thesis would not have been completed without his divine guidance.

Firstly, I would like to express my sincere thanks to my supervisor, Prof. Dr. Chong Kuan Eng for his patience, guidance, advice, and motivation to complete this dissertation since the very beginning. Many thanks also to Universiti Teknikal Malaysia Melaka and Ministry of Higher Education, Malaysia for the financial supports.

Muhammad Faishal and Hafizh Musthafa Faishal who are always beside me, believing in me, and encouraging me in the good things. The understanding, support, and patience of them are ark for me to stare the future wiser. I will always be grateful to my beloved parents, Achmad Kartubi, Qurrotu Aini, Muhtadi and Nunik Susiloningsih, for their prayers, love, and patience. The spirit of their prayers and smiles is always adorned the peace of this heart to pursue a dream. Also, perfect thing cannot be achieved without their sincerity.

I also want to thank my lovely sisters and brothers, Hayati Puji Astuti, Muhammad Farisa Siraj, Farah Faricha, Ainun Na'im, and Aiza Nur Adlia, who always giving me a support and cheerfulness. Lastly, friendship and togetherness have been always there for all my Indonesian and Malaysian friends. A beautiful moment and word of thanks always decorate for laughter and discussions with you all.

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RO	-	Robust Optimization
GA	-	Genetic Algorithm
HDD	-	Hard Disk Drive
CVP	-	Cost-Volume-Profit
RMTM	-	Robust Optimization of Mixed-Load Tester
TFT - LCD	-	Thin Film Transistor - Liquid Crystal Display
NSGA - II	-	Non Dominated Genetic Algorithm II

LIST OF PUBLICATIONS

Asih, H.M., Chong, K.E., and Ph'ng L.M., 2018. Simulation of Mixed-Load Testing Process in an Electronic Manufacturing Company. In: International Conference and Workshop on Telecommunication Computing Electronics and Control 2018, Yogyakarta, Indonesia, 18 - 20 September 2018.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The electronic industry is a complex manufacturing system due to the high technology development, high product varieties and high production volume. These characteristics result in disruptions within the production process such as low machine utilization, low throughput and high work-in-process. Furthermore, many uncertainties which can influence the production performance occur in the real world. These uncertainties include machine breakdown (Xu and Zeng, 2012), demand changes (Barahona et al., 2005; Lin et al., 2014; Albey et al., 2015; Ardjmand et al., 2016; Chou et al., 2016; Maggioni et al., 2017), processing time (Guo et al., 2013; Gyulai et al., 2015; Sakhaii et al., 2016), cost parameter (Maggioni et al., 2017), capacity (Corolli et al., 2014) and price (Rentizelas et al., 2012; Akbari et al., 2014; Verma et al., 2014; Zhang and Jiang, 2016). Hence, these industries are forced to improve continually the productivity in order to provide high profit and achieve the customer demand as well.

To support high volume manufacturing and high product varieties on an economical scale, the company is continuously looking for advanced technology testing equipment. The utilization of tester is one of the performance measures that is considered by companies. One of the important aspects of capacity planning is dealing with maximization of machine utilization; with the ability to lower the allocation of the machine and fulfil more product demand while satisfying the technological and customers' needs (Yusof and Deris, 2010).

The advanced technology testing equipment has higher flexibility and higher quality. This flexible capability, by simply re-programming the testing equipment, may increase the varieties of the products and reduce the set-up time and quick cell creation for a new product family. One of the main issues in the testing process environment is how the products are allocated or loaded into each tester.

This research was conducted based on a case study from a multinational hard disk drive (HDD) company in Malaysia. There was memorandum of understanding (MoU) between Universiti Teknikal Malaysia Melaka (UTeM) – Faculty of Manufacturing Engineering and the HDD company. The observations of the production process and from the discussions with the managers, IE planner, plant supervisors and production line associates found that the characteristics of the automated testing process are complex.

HDD is a data storage that provide relatively quick access to large amounts of data on an electromagnetically charged surface or set of surface. The automated testing process is one of the most complicated area in an HDD manufacturing system (Samattapapong and Afzulpurkar, 2016). There are many automated testing machines, each containing around 2880 slots for testing individual disk drives. All the automated testing machines has capability to load and test different hard drives simultaneously, called as mixed-load tester. There are two types of hard drives, 2.5" inch for laptop usage and 3.5" inch for PC usage. Each hard drives type has many models that are different testing durations and different routes. Besides that, the robot capability to load and unload hard drives to each slot needs to be considered. In addition, many uncertainties in shop floor makes the problem more challenging. It results in complex capacity planning and product allocation.

Therefore, a novel hybrid methodology was proposed to solve this problem. First of all, robust optimization model was developed by integrating the mathematical model, robust optimization, and genetic algorithm to optimize the number of the mixed-load testers required to achieve the production target by considering uncertain demand and testing time. Then, the simulation model was developed to validate and evaluate the tester utilization and throughput of the proposed models. Finally, a cost-volume-profit analysis was proposed to measure how many units must be sold or how much money must be earned to break even.

1.2 Research Problem

The research is based on mixed-load machine problem. This problem is categorized by multiple products that can be processed simultaneously with different processing time. The problem is further complicated with high product varieties and high demand variabilities. This research was conducted based on data collected on a backend process from a multinational manufacturing company in Malaysia that produces hard disk drives. The backend process is a testing and inspection process after the completion of a one piece flow from front-end process. One of the main processes is the automatic testing process. Currently, the testing equipment in the company mostly uses automatic testers. These testers are capable of supporting testing processes based on the products' configuration.

In the automated testing process, there are two stages of testers: Tester P and Tester Q to conduct testing operations for Product A, Product B, Product S, and Product T which already represent almost 98% of total throughput. Based on the observations conducted, Tester P and Tester Q have different functionality but have similar procedure processes. Tester P has the ability to check mechanically for HDDs and communicates with the information system after finishing the testing. Then, Tester Q is for testing HDDs under a controlled temperature with an interface circuit card in order to communicate with the information system when writing data signal into the HDD. Both tester stages have almost three thousand slots per tester that are able to test various product families simultaneously, known as mixed-load tester. Then, each slot consists of two cells that have to be loaded with the same product family.

The products produced in this company have high varieties of product families and models. Each product family has several models with different testing durations. Each product family has their own process flows and production volumes. Another constraint is there is a robot inside each tester to load and unload a product to each cell. On the real shop floors, one of the issues was the low-testing time product that makes the robot is so busy to load and unload products. It effects on not all slots inside the tester fulfilled, which results in low tester utilization of about 71%, well below the company's target of 96% (please refer to Figure 1.1). Consequently, the performance of the robot needs to be considered in planning the capacity and allocating the products to each mixed–load tester. In addition, the uncertain demand and also uncertain testing time in the real manufacturing system makes the problem more complicated. Investing the more resources will result in higher probability of meeting demand but higher cost to break even. These complexities make the real shop floor in the automated testing process was difficult to be managed. Hence, capacity planning and products allocation are very challenging.

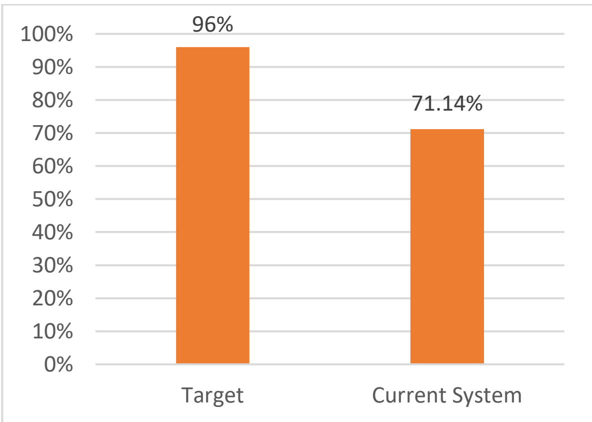

Figure 1.1 Average Tester Utilization: Current System versus Target

1.3 Research Questions

Based on the research background and research problems presented above, the research questions of this research are as follows.

i) How to develop models of robust optimization for capacity planning of a mixed-load tester that considers uncertain demand and testing time?

ii) How to develop simulation models to evaluate robust optimization models for mixed-load tester under uncertain demand and testing time?

iii) How to determine break-even point using a cost–volume–profit analysis for the proposed robust optimization models?

1.4 Research Objectives

The main aim of this research is to improve tester utilization while achieving the production target under uncertain demand and testing time and also to determine the break-even point on the testers required. More precisely, the research objectives are:

i) To develop robust optimization models for mixed-load testers in capacity planning under uncertain demand and uncertain testing time.

ii) To evaluate the robust optimization models for mixed-load testers that considers uncertain demand and uncertain testing time through simulation approach.

iii) To develop a cost–volume–profit analysis for the proposed robust optimization models.

1.5 Research Scope

The limitations of this research are as follows:

i) This is a case study on the advanced technology automated testing process of a HDD manufacturing company in Malaysia. It was based on memorandum of understanding

(MoU) between Universiti Teknikal Malaysia Melaka (UTeM) – Faculty of Manufacturing Engineering and the HDD company. The observations of the production process and from the discussions with the managers, IE planner, plant supervisors and production line associates found that the characteristics of the automated testing process are complex.

ii) This research focuses on four big product families that already represent almost 98% of the total throughput, namely product A, product B, product S, and product T. They have different testing process flows in Tester P and Tester Q. Each product family has its own models with different testing durations.

1.6 Significance of Research

In the automated testing process, there are high product varieties and volumes to be tested. Each product has different testing durations and routings. In addition, the capability of a tester that can test and load multiple product families simultaneously, called by mixed–load tester. These complex characteristics of the system makes the problem more challenging. This research acts as a pioneer project to investigate capacity planning and allocation under demand and testing time uncertainty for mixed-load tester problem. It could help the planner avoid frequent re-adjustment of the planning that can disturb the process in the real shop floor.

In addition, this study will provide a novel hybrid methodology in solving capacity planning and allocation problem under uncertainties. A proper validation for the proposed solution will be carried out to ensure their applicability and to evaluate the performance measures of this manufacturing system. In addition, a financial report will be presented as well to help decision maker choose the scenarios from the proposed solutions. From the literature review that has been conducted, few researches discuss on such problem.