Faculty of Manufacturing Engineering

A LAYOUT OPTIMIZATION APPROACH FOR RECONFIGURABLE CONVEYOR SYSTEM USING SIMULATION TECHNOLOGY

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DECLARATION

I declare that this thesis entitled " A Layout Optimization Approach for Reconfigurable Conveyor System using Simulation Technology" is the result of my research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature: .....

Name: LING YEE NI

Date: .....

APPROVAL

I hereby declare that I have read this dissertation/report and in my opinion, this dissertation/report is sufficient in terms of scope and quality as partial fulfilment of Master of Manufacturing Engineering (Industrial Engineering).

Signature: …….....

Supervisor Name: IR. DR.-ING. AZRUL AZWAN BIN ABDUL RAHMAN

Date: …….....

DEDICATION

Thanks to my parents,
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ABSTRACT

Simulation software has been widely used nowadays. It is useful in the manufacturing sectors, especially in the fourth industrial revolution due to simulation software can provide ideas on how to model, simulate, analyse, and optimize the whole production systems without interrupting the real system. There are lots of simulation software in the market and use in different areas with different functions. The software used in this paper is the Tecnomatix Simulation software. The main purpose of this study is to present a layout optimization approach for the reconfigurable conveyor system. The approach is presented in the form of the user interface and the user interfaces are built for the straight-line conveyor and the curve conveyor using the element of dialogue in the software. This dialogue is formed with the assist of the programing language in the simulation software. The layout of the reconfigurable conveyor system able to optimize by optimizing the results of the speed of the conveyor and the throughput of the conveyor. The results can be optimized with the help of the defined parameters of the conveyor which are the width of the conveyor, the length of the conveyor, the number of conveyors, the degree of angle for the curve conveyor, the time is taken from the input to the output station, the density of the materials placed on the conveyor, and the size of the materials. The user interfaces for the curve conveyor able to optimize the layout with the degree of angle in the range of larger than 0º but lesser or equal to 90º due to the sine function of the calculation in the SimTalk. The studies of attributes were carried out to declare the parameters needed for the layout of the conveyor system before implementing the parameters into the user interface. There are two main categories for the parameters which are the defined parameter and the driven parameters or named as dependent parameters. The speed of the conveyor and the throughput of the conveyor are categorized under the group of driven parameters which meant that they are depending on the defined parameters. Once the defined parameters changed, the values change of driven parameters will happen.

PENDEKATAN PENGOPTIMUMAN TATA LETAK UNTUK SISTEM KONVEYOR YANG DAPAT DIKONFIGURASI ULANG MENGGUNAKAN TEKNOLOGI SIMULASI

ABSTRAK

Perisian simulasi telah digunakan secara meluas pada masa kini. Perisian simulasi digunakan dalam sektor pembuatan, terutama dalam revolusi industri keempat ini kerana perisian simulasi dapat memberikan idea tentang bagaimana memodelkan, mensimulasikan, menganalisis, dan mengoptimumkan keseluruhan sistem pengeluaran tanpa mengganggu sistem yang sebenarnya. Terdapat banyak perisian simulasi di pasaran dan digunakan di kawasan yang berbeza dengan fungsi yang berbeza. Perisian yang digunakan dalam projek ini adalah Perisian Simulasi Tecnomatix. Tujuan utama kajian ini adalah untuk memberi idea tentang bagaimana mengoptimumkan jarak sistem penghantar yang dapat dikonfigurasi semula. "User Interface" untuk penghantar garis lurus dan penghantar lengkung menggunakan elemen dialog dalam perisian komputer telah disaji dalam projeck ini. Dialog ini dibentuk dengan bantuan bahasa pengaturcaraan dalam perisian simulasi. Susun atur sistem penghantar yang boleh dikonfigurasi semula dan dapat dioptimumkan dengan mengoptimumkan hasil kelajuan pengangkut dan hasil penghantar. Hasilnya dapat dioptimumkan dengan bantuan parameter konveyor yang ditentukan iaitu panjang penghantar, darjah sudut untuk penghantar, masa dari input ke stesen output, ketumpatan bahan yang ditempatkan pada penghantar, dan size permukaan bahan. Antaramuka pengguna (user interface) untuk kurva penghantar dapat mengoptimumkan susun atur dengan tahap sudut lebih besar daripada 0º tetapi lebih rendah atau sama dengan 90º dengan menggunakan fungsi pengiraan sinus di SimTalk. Kajian atribut dilakukan sebelum menghasilkan "user interface". Terdapat dua kategori utama untuk parameter yang merupakan parameter yang ditentukan dan parameter yang didorong atau dinamakan sebagai parameter yang bergantung. Kelajuan penghantar dan kelajuan penghantar dikategorikan di bawah kumpulan parameter yang didorong dengan sebab ia bergantung pada parameter yang ditentukan. Nilai parameter yang didorong akan berubah jika parameter yang ditentukan berubah.

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LIST OF ABBREVIATIONS

CNC	-	Computer Numerical Control
DML	-	Dedicated Manufacturing Lines
Etc.	-	Et cetera
FMS	-	Flexible Manufacturing Systems
GA	-	Genetic Algorithm
RCS	-	Reconfigurable Conveyor System
RMS	-	Reconfigurable Manufacturing System
RMT	-	Reconfigurable Machine Tools
UI	-	User Interface
UTeM	-	Universiti Teknikal Malaysia Melaka

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The manufacturing industry went through three revolutions in the past century. The manufacturing industries in the contemporary are still exposed to the challenges not only improve the ability to adapt to the global marketplace (Ailing, C., 2009). Due to technological advancement, the trend of automation is inevitable, and automated equipment has been created to replace manual power supplies, thereby reducing costs (Chen *et al.*, 2019). IT solutions become more and more common tools to optimize the systems not only for materials handling but also for the parameter of the performance (SIDERSKA, 2016). The most familiar tools used by industrial or production engineering are computer simulations (SIDERSKA, 2016). Computer simulation is a method that attempts to use the mathematical model of a computer program to carry out the real process in the real world (Grabowik *et al.,* 2018). This kind of simulation is widely used to refer to processes where direct observation is impossible, such as weather forecasting, stock trading behaviour prediction, etc (Ćwikła G and Foit K, 2017). The simulation software that will be used in this project is the Tecnomatix Siemens Plan Simulation to come out with an approach that can optimize the layout of the reconfigurable conveyor system.

Besides, the life cycle of the product becomes shorter in today's fiercely competitive market. The important keys to competition with competitors are the customers' demand for the number and type of product changes, and rapid response (Aboufazeli, N., 2011). To meet

these requirements, reconfigurable manufacturing systems (RMS) are developed. RMS provides short-term adaptability for its functions and capabilities (Youssef, A. M. A., and Elmaraghy, H. A., 2000). The combination system involved Dedicated Manufacturing Lines (DML) and Flexible Manufacturing Systems (FMS) is the system used in most manufacturing industries to produce their products (Youssef, A. M. A., and Elmaraghy, H. A., 2000). RMS can respond quickly and effectively to changes (Koren, Y., Gu, X. and Guo, W., 2017). This is due to RMS combines the high throughput of DML and the flexibility of FMS. RMS provides the required functions and capacity. RMS is a static system which contrary to traditional DML and FMS (Koren, Y., Gu, X. and Guo, W., 2017). RMS has many aspects of reconfiguration and one of the aspects is the reconfigurable conveyor system. The conveyor system is one of the material handling systems used in manufacturing industries (Mohamad, N. R. *et al.,* 2018), and this system able to transport products effectively (Dematic, 2014).

Conveyor systems generally play an important role in industry and economy sectors. The trend is to continue automation of transportation, storage, production lines, and others. In addition, this focus of automation is becoming increasingly important to reduce costs. Thus, the ways to improve and optimize the conveyor system become a more interesting topic currently and also in the near future. Based on the above facts, layout optimization and simulation are two tasks that are critical to any facility planning and layout research (Grajo, 1996). This project aims to provide an approach to optimize the layout of the reconfigurable conveyor system. A user interface in the dialogue form will be established based on the scenario.

1.2 Problem Statement

The only way to remain competitive in the global market is by simplifying the flow of material (Allred, 1996). Productivity will increase and the performance of delivery will improve by having this simplification. Unfortunately, to smoothen the flow of materials is not an easy task especially in the assembly lines. This is due to the assembly lines need to have spaces for the storage of components that needed to assemble in a short while. However, the workstations have limited space that might not enough for the components to store in the assembly areas. In the same way, the replacement of the material consumed within a convenient time interval to maintain the assembly operation is also important. According to Domingo et al. (2007), the companies are facing a trade-off between the supply of materials to assembly lines that have higher delivery performance or keep the buffer level of the workshop at a low level. Allred (1996) pointed out that there will be a dramatic drop in productivity when the workstation or point of use unable to obtain the required materials when needed. This is the biggest reason for the low efficiency of the factory.

Layout design involves the physical layout of many interactive facilities on a specific site. In the design stage by regardless of the type of facility, the common features of all facilities in the area and shape of the facility are always the main concerns. One of the most critical issues in the design of the flows of conveyor systems that needed to solve by the designers in the earlier stage is how to design the layout in an optimum way. Manufacturers are trying their best to improve their production activities in the terms of productivity and efficiency due to the challenges in the unpredictable demand patterns, product life cycles become shorter, and customized products happened in the market nowadays. The conveyor systems have to give a fast respond or adjustment based on the changes in the product designs and demands of the product without the need for huge investments.

Due to the impact of layout on material handling costs and time, the development of layout for the reconfigurable conveyor system is an important step in designing production

equipment, which will affect the overall productivity of the workshop. The poor layout will cause more parts to move from one machine to another and take longer, leading to increased material handling distance or cost.

1.3 Objective

- To study the concept and the parameters that affected the layout performances of the reconfigurable conveyor system
- To design and develop user interface(s) that able to assist the user to optimize the layout for the reconfigurable conveyor system using Tecnomatix simulation software

1.4 Scope of the study

In this project, the created user interfaces have limited uses. The user interfaces only applicable for the optimization happened in the straight-line conveyor and the curve conveyor. The layout of the conveyor system is optimized by referring to the speed and the throughput which are the dependent parameters under the studies of attributes. Studies of the attributes for the parameters involved in the layout of the conveyor system are needed in this project. Tecnomatix Siemens Plan Simulation is the software that used to form the user interfaces using the element of dialogue in the software with the assists of callback argument in the programming language SimTalk.

1.5 Thesis Organization

This project is slipped into two Master Project 1 and Master Project 2. This project is conducted in Semester 2 and Special Semester. The structure of the thesis is drafted in

Figure 1.1. The first chapter which is the chapter of introduction includes the background, problem statement, objectives, and scope of this thesis. Chapter 2 which is Literature Review will be done throughout the whole project. The contents in chapter 2 will involve the knowledge from previous researchers. Next, the third chapter will cover the methods and procedures described in doing the project. Project results and discussion will be covered in chapter 4 including the drawings and the analysis of the layouts. Lastly, the conclusion and improvement will be covered in chapter 5.

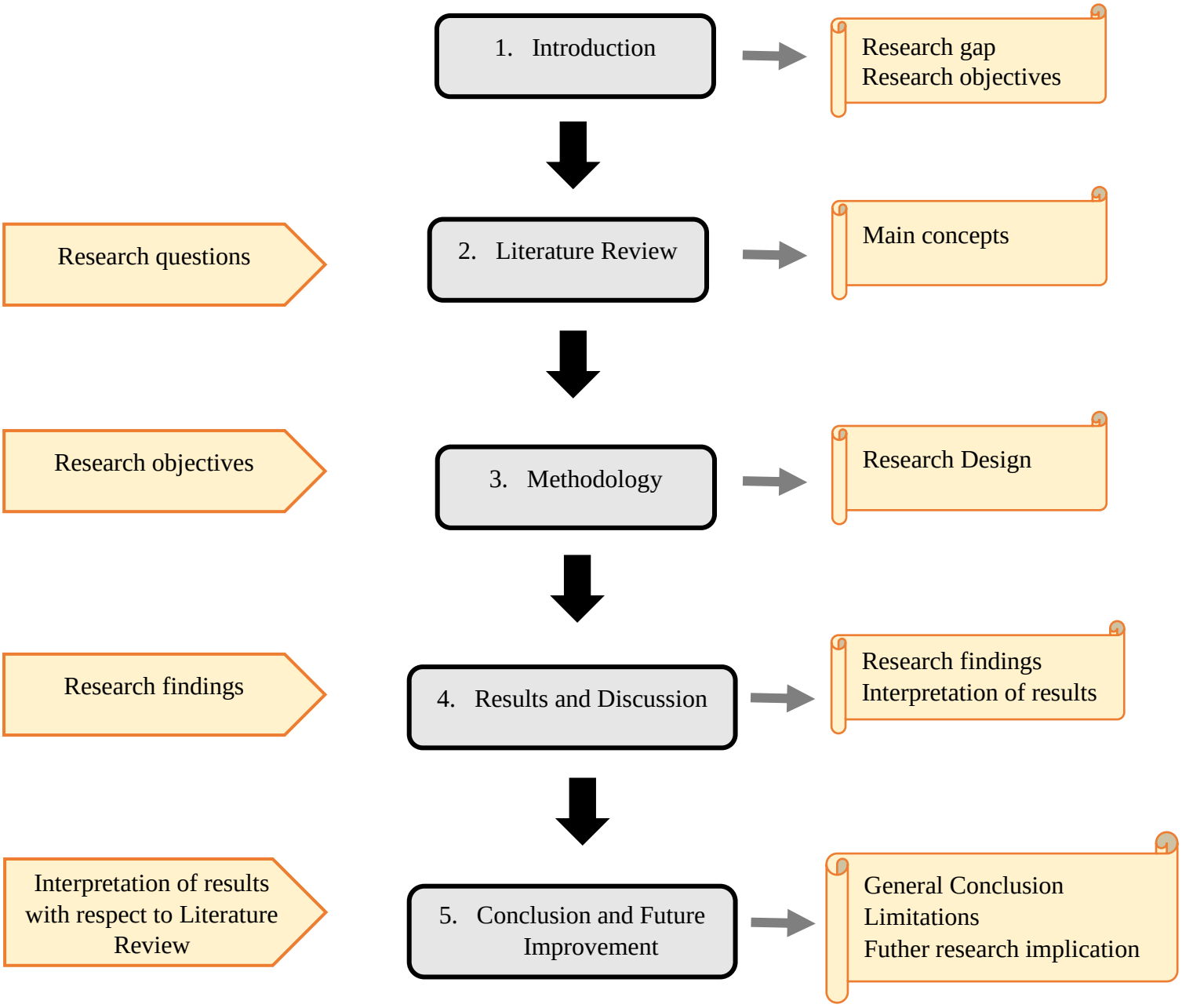

Figure 1.1: Thesis Structure

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The reviews regarding the manufacturing system, dedicated manufacturing system (DMS), flexible manufacturing system (FMS), reconfigurable manufacturing system (RMS), features and principles of RMS, procedures to implement RMS, problems faced when implementing RMS, material handling, conveyor system, the layout of the material handling system, previous studies on the design problem for the conveyor layout, generation and evaluation reconfigurable layout framework, reconfigurable conveyor system, modelling and simulation, development of simulation models, simulation analysis, advantages of simulation, limitations of simulation, and Tecnomatix Plant Simulation software are provided in this chapter.

2.2 Manufacturing System

There are lots of challenges and changes that characterize the environment industry currently. Volumes of product change and mix constantly are the problem faced by the typical manufacturing industries. At the same time, the production environment has been rapidly developed in materials engineering and manufacturing technology. Composite materials that are light in weight and with better material properties are trying to take over the use of traditional materials. Most of the composite materials have a stronger tensile

strength and better absorption of vibration compared to the traditional. Other than the issues of materials, the technology of machinery also changes rapidly. The conventional manufacturing processes such as milling, turning, sawing, etc. are replaced by the non-traditional manufacturing processes such as Ultrasonic Machining, Electro-discharge Machining, Water Jet Machining, etc. These changes will not have an end in the short while due to the manufacturing sectors still bring a huge advantage to the economy. Based on the National Research Council (1998), there is a committee called "Visionary Manufacturing Challenges for 2020" conducted a Delphi survey and a seminar. They claimed that there are two major inventions or innovations that can be used to promote fundamental changes in users or cultural capabilities which are the equipment and processes that are adaptable and also the reconfigurable operations of manufacturing. The companies are still able to gain their profit and maintain productivity in the year 2020 by having the two requirements that stated before. The committee declared six challenges or targets that the companies will be facing in the year 2020 and the two requirements stated before are the two targets out of the six of them.

The sizes of the machines no need to be bulky and complex with the advance of the machinery and materials. The weight of the material handling systems will be reduced due to the lightweight of the payload. In the future, the configuration and reconfiguration of the machines and equipment involved in material handling may happen monthly. This is due to the lightweight of machinery and equipment in the system. The main advantage of the reconfiguration layout is the equipment can be reconfigured according to the new product mix and quantity when the product mix and quantity change. The costs for material handling able to reduced when the layout is optimized with the one requirement is that the cost of reconfiguration layout must be enough to offset the cost for moving the machinery and equipment from current points to the suggested points. The possibility to optimize the

performance of the operation increase by having a layout with a lifespan that is short in term. The availability of data from production also one of the causes that increase the possibility of optimization. The performance of operations involves part cycle times and inventory left in the process. All in all, in a sense, the potential for frequent layout changes have therefore transformed the modern layout problem from a strategic problem. This will only consider long-term material handling costs to a tactical problem, which considers operational performance measures such as reducing product flow. When changing from one layout configuration to another, the material handling and machine relocation costs, time, work-in-process inventory and maximum productivity are also considered.

Based on Groover (2008), the manufacturing system involved three major components which are personnel, equipment, and procedures. Without these three components, the manufacturing systems unable to declared as a complete manufacturing system. Unique products are formed when involved in different programs, equipment, and personnel. The manufacturing systems can be conducted in different styles by organizing the same person and the same equipment in different ways. The rapidly changing market forces the company to constantly reorganize its product manufacturing methods.

Manufacturing systems involve three evolutions. It started with a traditional manufacturing system to a conventional manufacturing system and now comes to an advanced manufacturing system. The development of reconfigurable manufacturing systems declared by the example of these systems. Each manufacturing systems have their strengths and weaknesses. They come out with their particular application based on the needs of the markets.

2.2.1 Trends and Motivation in Industry

In the field of manufacturing processes and materials, the developments in the side of technology point toward the next generation of manufacturing systems. The adaptability, agility and speed of reconfiguring will become more stable and better in the next generation due to the technology developments. There are few sectors of industries with manufacturing and assembly workstations that are lightweight such as the clothing manufacturing industries, household appliances, etc. can be easily moved from the original positions to the new positions.

In the side of materials, the primary materials that use to manufacture the discrete parts change from the conventional materials to the composites materials (Heragu and Kochhar, 1994). Based on Arimond and Ayles (1993), the components that manufactured using the aluminium replaced by the composite due to several advantages. The most common example that replaces the cast aluminium into the composite material is in the aerospace manufacturing industry. The advantages of having composite materials are they are light in weight, harder, higher resistance to heat, higher strength in tensile, and better absorption in vibration. All of these properties able to let the products been designed into the products that able to move easily and quickly by having the similar functions as the previous products, without any the complex foundation and in the lighter weight. The material properties are not the only way to make a product into the lighter in weight. The processes that used to manufacture them also carried the large responsibility. The advanced manufacturing processes such as cut the materials using the laser beam, harden the materials using an electron beam, nano-technology, etc. able to provide support for machine tool designers seeking to manufacture lightweight processing equipment (Asari, 1993). There was a product developed a few years before named as the permanent magnetic sucker and it is used to install and remove the tools in a more efficient way. The machines and tools that applied this sucker will not be hindered or magnified by the sucker and the sucker carries

energy by its own. These features themselves once again support rapid device reconfiguration.

Some useful examples regarding the practices in industry sectors and the researches in academic sectors are pointed out in the articles with the title of "Next Generation Factory Layouts: Research Challenges and Recent Progress" written by Benjaafar et.al. in the year 2000. The examples provided give a clearer vision or target for the next generation on how to achieve the systems with higher adaptability and able to reconfigurable in a shorter period. One of the examples given in the article is related to the Intelligent Manufacturing Systems and these systems dedicated to the development of multifunctional machine tool technology with adjustable capacity. The easier way to upgrade the machinery and tools with better capacity, function and the efficient is to change their ordinary software and hardware to the modular form (Ikegaya, 2000). The reason to change from ordinary or traditional styles into the modular software and hardware is to make sure that the system itself able to follow the trend of the current production environment. Besides, there is one company mentioned in the article and this company named Turmatic System Inc located in the United States. This company launched a product that allows up to seven processing units to be processed at the same time and can be modified by other machinery processes. Besides, milling machines in the market normally huge in size but the milling machines produced by Southwestern Industries Inc are portable and easy to move along narrow space in the production plant (Benjafaar *et. al.,* 2000).

2.3 Dedicated Manufacturing System (DMS)

The automated processes that are fixed and with low cost are the characteristics of DMS. It has a mass production to produce the major products in the industry. Each of the