DEVELOPMENT OF A SIMULATION AIDED RECONFIGURE TOOL FOR HYBRID ASSEMBLY SYSTEM

Submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Hons.)

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirements for the Degree of Bachelor of Manufacturing Engineering (Hons.). The member of the supervisory committee is as follow:

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ABSTRAK

Sistem pemasangan hibrid adalah kaedah yang bertuju kepada produk-produk yang berbeza yang ada di pasaran. Sistem ini digunakan untuk melengkapkan proses pemasangan di kedua-dua stesen iaitu stesen pemasangan manual dan juga automatik. Dalam industri semasa, susunan peralatan manual kebanyakannya dikendalikan oleh operator. Para operator hanya bergantung penuh pada bakat dan kemahiran mereka untuk memasang komponen dan sub-pemasangan untuk menghasilkan produk yang lengkap. Masalah ini dapat ditangani dengan kaedah konfigurasi semula untuk sistem pemasangan secara hibrid dengan bantuan simulasi serta membuat penilaian terhadap keberkesanan kaedah konfigurasi semula dengan mengurangkan peratusan penyekatan sebelum proses kesesakan. Selaras dengan objektif penyelidikan ini, model simulasi ini telah dibangunkan dengan bantuan *Tecnomatix Plant Simulation*, yang merupakan sebuah perisian yang menyerupai sistem sebenar sesebuah proses pemasangan yang nyata. Pemahaman yang lebih mendalam mengenai komponen sistem pemasangan, analisis komponen dan kajian terhadap masa pemprosesan produk telah dijalankan. Seterusnya, konfigurasi semula struktur proses pemasangan dijalankan setelah analisis tersebut dipertimbangkan. Proses konfigurasi semula struktur dicapai dengan menggunakan model simulasi, dimana melibatkan penyusunan semula urutan proses yang berbeza dan yang mampu berjaya. Akhir sekali, susun atur konfigurasi semula yang sesuai berjaya ditemui untuk setiap produk dan susun atur yang dikonfigurasikan semula dipilih dengan mempertimbangkan peratusan penyekatan minimum sebelum proses kesesakan dan peratusan kerja tertinggi dalam sesebuah sistem pemprosesan.

ABSTRACT

A hybrid assembly system is a method aimed toward the product variation present in the market. This system uses both manual and automated assembly stations to complete the assembly process. In the current industries manual equipment arrangement is mostly conducted by human operators who use their inherent talent, skill and judgment to assemble the components and subassemblies into a finished product. In order to solve this issue, this study aims to develop a simulation-aided reconfigure tool for hybrid assembly systems and to evaluate the effectiveness of reconfigurable tools by minimizing the blocking percentage before the bottleneck process. In accordance with the objectives of this research, simulation models were developed with the help of Tecnomatix Plant Simulation, a software that simulates the actual system in a computer environment. In addition, to gain a better understanding of the assembly system components, part analyses and time studies of product and process processing times were conducted. Then, a structural reconfiguration takes place while the analysis is considered. The structural reconfiguration was achieved by utilizing a simulation model, which involved rearranging the many process sequences that could take place. Finally, a suitable reconfigured layout was discovered for each product. The reconfigured layouts are chosen by considering the minimum blocking percentage before the bottleneck process and the highest working percentage.

DEDICATION

Only

my beloved father, Rajandren

my appreciated mother, Nirmala

my adored sisters, Uthaya Chandrika, Latha Raj, Lalitha Raj and

my supportive fiance, Viswa Ram

for giving me moral support, encouragement and also understanding.

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RAS	-	Reconfigurable Assembly System
RMS	-	Reconfigurable Manufacturing System
DES	-	Discrete Event Simulation
FAS	-	Flexible Assembly System
PLM	-	Product Life cycle Management
MOM	-	Manufacturing Operations Management
CNC	-	Control Numerical Control
RMT	-	Reconfigurable Machine Tools
CAD	-	Computer-Aided Design
KBE	-	Knowledge-Based Engineering
CAE	-	Computer-Aided Engineering
HTM	-	Homogeneous Transformation Matrix
EA	-	Evolutionary Algorithm

CHAPTER 1

INTRODUCTION

1.1 Research Background

Customers' requirements are becoming more variable and customized as time goes on (Koren *et al*., 2018). Thanks to the advancement of computer-aided manufacturing simulation, customized items can be made at an affordable price, moving the manufacturing paradigm away from large-scale customization and toward large-scale individualization (Ashima *et al*., 2021). One of the most significant challenges for mass individualization is the large number of different modules combined into a complex product (Koren *et al*., 2015a). As a result, the manufacturing system must be able to manufacture a huge number of unique models, and it must be a Reconfigurable Assembly System (RAS) (Cohen *et al*., 2017).

Assembly is a procedure that brings subassemblies and components together to construct a finished product. Assembly lines in which products are moved from one station to another are typical of arranging stations in various industries, including manufacturing (Bi *et al*., 2008). The finished product takes shape gradually, beginning with a single component known as the base section. The remaining components are assembled at various stages throughout the process (Pierre De Lit, 2003). The reconfigurable tools for assembly systems are commonly manual processes based on human experience or logic, which is still the most common and traditional assembling method for current industries (Ali-Qureshi and ElMaraghy, 2014a).

In assembly, the RAS concept is a variation of the Reconfigurable Manufacturing System (RMS) concept (Huettemann *et al*., 2016). RAS should be scalable to meet greater demand variations and it should be convertible to manage multiple variants and new items (Koren *et al*., 2015b). RAS design concerns involve a complex interaction between different machines, line balance and production schedule. In addition, new metrics are required to quantitatively evaluate the complexity of the system configuration and the product's features and functions (Hu *et al*., 2011a). A new system layout for the present RAS should be developed to improve the system's efficiency while also lowering operating costs. Depending on many product variants, different combinations of components should be installed for the sequence the process takes (Antzoulatos *et al*., 2017). Several stations serve multiple product varieties in the systems and all of them will share it.

Every simulation programme is now employed almost in manufacturing industries (Yolanda Carson and Maria, 2015). Programs that simulate manufacturing processes are used to test the consequences of various model decisions and evaluate production capabilities, duration of operations, and other manufacturing characteristics (Roci *et al*., 2022). Additionally, the simulation eliminate the chance of introducing a change into a process that would damage the overall system (Václav *et al*., 2017a). One of the most important goals of the simulation is to represent the real system virtually (Olexová and Gajdoš, 2016). Therefore, Discrete Event Simulation (DES) models for each of the reconfiguration scenarios were developed to evaluate the effectiveness of the reconfiguration tools and carry out the last steps of the decision-making logic, which were to be decided among the reconfiguration solutions (Michalos *et al*., 2016).

1.2 Problem Statement

It is common for customer requirements to evolve quickly in today's production environment. To compete in today's market, most manufacturing companies must offer many product variations with short lead times. Therefore RAS are getting more complex and facing more challenges (Orta and Ruiz, 2014a). Manufactured components and subassemblies are assembled to make a unit of a product. In the case of complex products in terms of the number of parts, Flexible Assembly Systems (FAS) are also designed as Manual Flexible Assembly Systems (Cohen *et al*., 2017b). Manual equipment arrangement is mostly conducted by human operators who use their inherent talent, skill and judgment to assemble the components and subassemblies into a finished product (Ali-Qureshi and ElMaraghy, 2014b). These assembly systems generally involve thousands of different pieces with various qualities. For example, employees must handle dimensions, weight, shape and frequency of use during assembly operations for every different piece to ensure that the system functions properly. In a manual assembly system, the quality of the parts has considerable impact on worker performance, productivity (Neumann *et al*., 2010).

1.3 Objective

The objectives are as follows:

I) To develop a simulation aided reconfigure tool for hybrid assembly system

II) To evaluate the effectiveness of reconfigurable tools by minimizing the blocking percentage before the bottleneck process.

1.4 Scope

The scopes of research are as follows:

I) DES technology will be used to model and reconfigure tools depending on many product variants with different combinations of components for the sequence the process takes in the assembly system at the Teaching Factory.

II) Reconfiguration scenarios were developed to evaluate the effectiveness of the reconfiguration tools and carry out the last steps of the decision-making logic, which were to be decided among the reconfiguration solutions.

1.5 Important of study

A huge amount of money and other resources are being spent on producing products that require different tools and configurations throughout the assembly line. So each tool is being changed or replaced by the workers according to the production requirements; the whole assembly line needs to be paused for a certain period. When reconfigurable assembly tools are present in that assembly line, the worker performance and productivity of products will increase; thus, human errors can be totally prevented. The RAS will take over the reconfiguration of tools while the assembly line will continue without being held. Moreover, this research can ease the workers or labour and management by making the assembly process more effective without errors. Eventually, it can prevent resource wastage and it will be more sustainable. In addition, this study can provide a permanent solution for the industry towards spending resources to produce products that need different tools and configurations on an assembly line.

CHAPTER 2

LITERATURE REVIEW

2.1 Simulation

Simulation is an experimental method that replaces a computer model for an existing system in completing the experiment (Vaclav *et al*., 2019). This simulation model can carry out several experiments, assess how well the system works, make adjustments to how the system is designed, and then apply those changes to the actual system. There is no alternative approach or theory that would enable people to conduct experiments with a complicated system before it is placed into action. No other method would make it possible to perform complex processes on the computer as a simulation that takes weeks or months when it is done manually. It is the preferred tool for decision-making in many different departments in a company (Orta and Ruiz, 2014b). The use of simulation has the benefit of being applicable virtually everywhere, besides the complexity of the system being modelled. Despite this, simulation analysis in companies located in underdeveloped countries is incredibly rare. Since simulation can simulate and model any business process, whether physical, informational, or decisional, it can assist us in various areas, including design, management, decision making, and production system (Mourtzis, 2020).

2.1.1 Discrete event simulation

DES is the process of developing a real system model and then using it to experiment, which is to better understand the system's behaviour or evaluate its performance. The experiment with the actual system and the experiment with a model of actual the stage can better understand the system (Babulak, E., and Wang, 2010a). Figure 2.1 shows the ways to study a system.

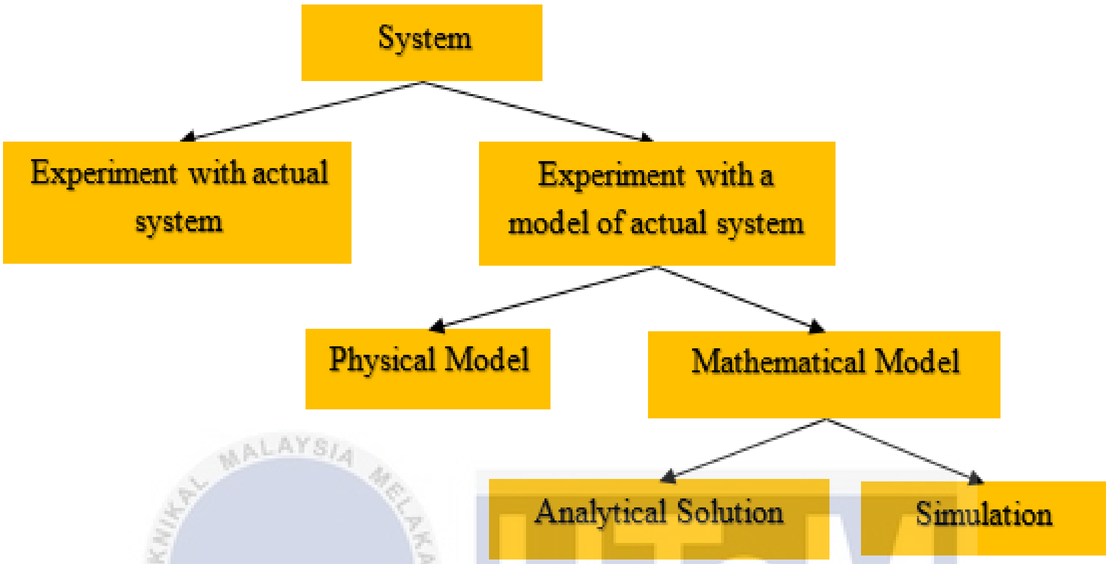

Figure 2.1: Ways to study a system (Babulak, E., and Wang, 2010b).

I) **System**

- Understanding of how the system works in the real world

II) **Experiment with the actual system**

- Acting a set of parameters collected from actual experiment

III) **Experiment with a model of actual**

- Defined as a set of parameters collected from actual experimental data or observations

IV) **Physical model**

- A technique for modelling and simulating systems that are based on physical components in an actual system

V) **Mathematical model**

- Collections of variables, equations, and initial values that come together to form a coherent representation of a procedure or activity

VI) **Analytical solution**

- An abstract form of mathematics that can be extended to fit for a variety of different working conditions

VII) Simulation

- Performance of a model in terms of time or space, which assists in the evaluation of the process of an existing system

2.1.1.1 Advantages of (DES) in assembly system

Implementing DES in assembly systems is beneficial because models can duplicate an existing system's operation and propose a new system that modifies the existing design (Detty and Yingling, 2000). According to Johansson (2014) DES is a tool to enhance the design of flexible assembly systems and the author's approach was focused on optimising the simulation process.

2.1.1.2 Simulation software

Tecnomatix Plant Simulation is an object-oriented 3D tool used to simulate discrete events. It enables users to design realistic digital logistic systems, thus allowing users to evaluate the features of the systems and optimise their performance. The programme is produced by the German company Siemens PLM Software, the established software supplier for Product Life cycle Management (PLM) and Manufacturing Operations Management (MOM). Production companies may find an efficient way to achieve their digital enterprises and apply innovations using the solutions that Siemens offers as part of its Smart Innovation Portfolio. Using digital models, it is possible to conduct experiments and test "what if" scenarios without disrupting the work of production systems or, in the case of the planning process, long before their assembly. This is made possible by the fact that digital models make it possible to perform experiments and test "what if" scenarios (Siemens. Plant Simulation, 2016).